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(54) **METHODS FOR DYNAMIC BEAMFORMING WEIGHT CONSTRUCTION BASED ON DIRECTIONAL MEASUREMENTS**

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H04B 7/06 (2006.01)
H04L 5/00 (2006.01)

(52) **U.S. Cl.**

CPC ***H04W 24/08*** (2013.01); ***H04B 7/0617*** (2013.01); ***H04L 5/0048*** (2013.01)

(58) **Field of Classification Search**

CPC . H04L 25/021; H04L 25/0224; H04L 5/0048; H04B 7/043; H04B 7/0617; H04B 7/0634; H04B 7/0695; H04W 24/08

See application file for complete search history.

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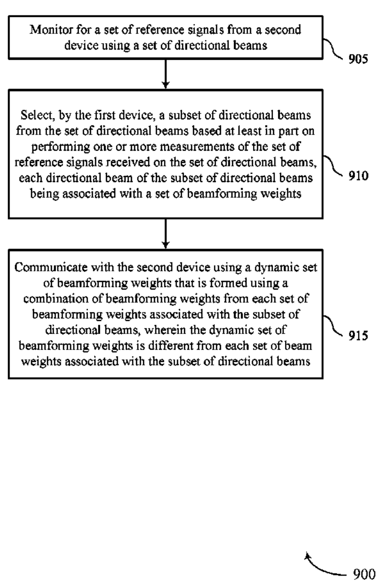
(57) **ABSTRACT**

Methods, systems, and devices for wireless communications are described. A first device may monitor for a set of reference signals from a second device using a set of directional beams. The first device may perform measurements on the received reference signals and select a subset of directional beams from the set of directional beams based on the performed measurements. Each directional beam may be associated with a set of beamforming weights. The first device may communicate with the second device using a dynamic set of beamforming weights. The first device may form the dynamic set of beamforming weights using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams. The dynamic set of beamforming weights may be different from each set of beamforming weights associated with the subset of directional beams.

25 Claims, 10 Drawing Sheets



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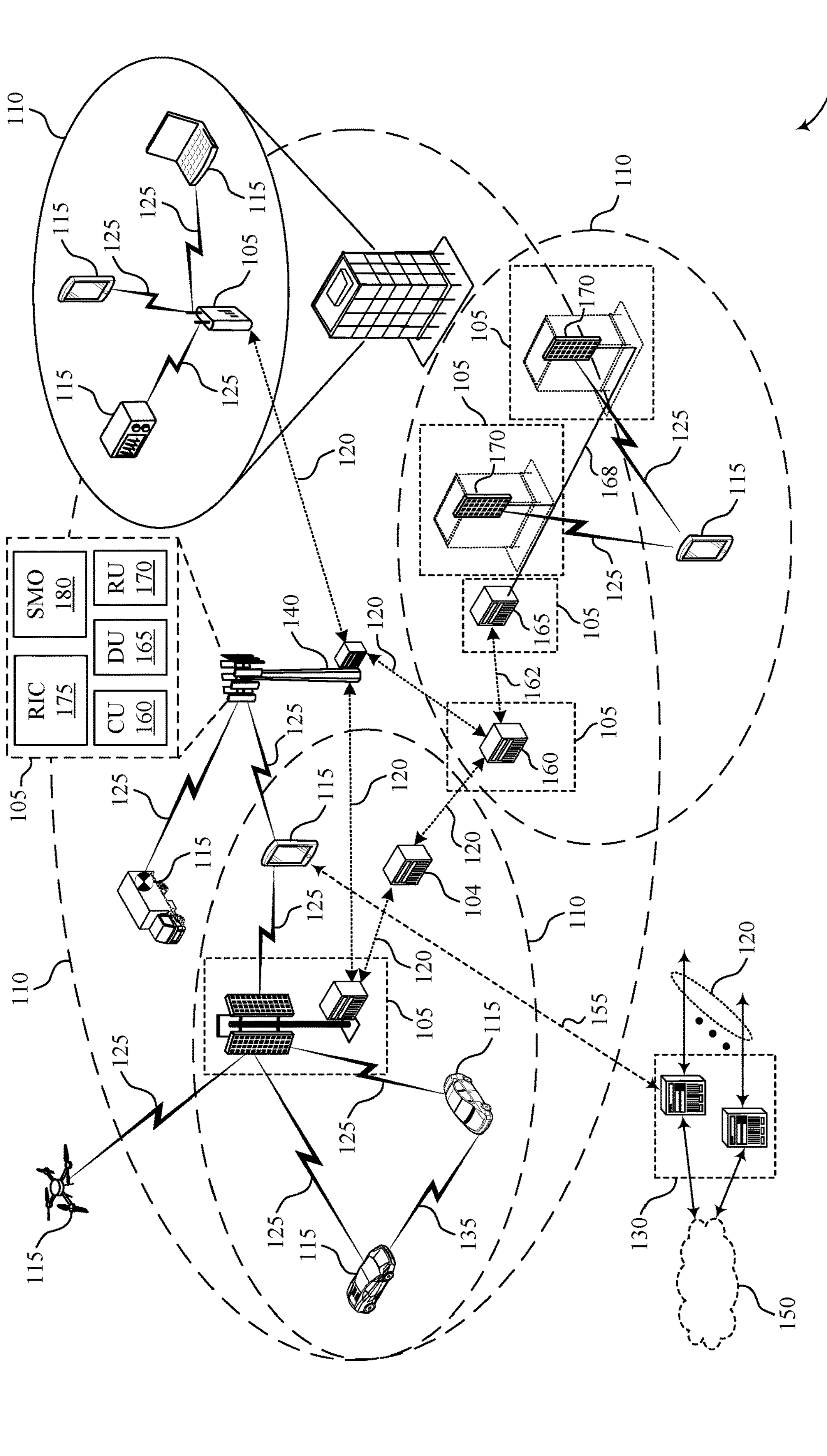
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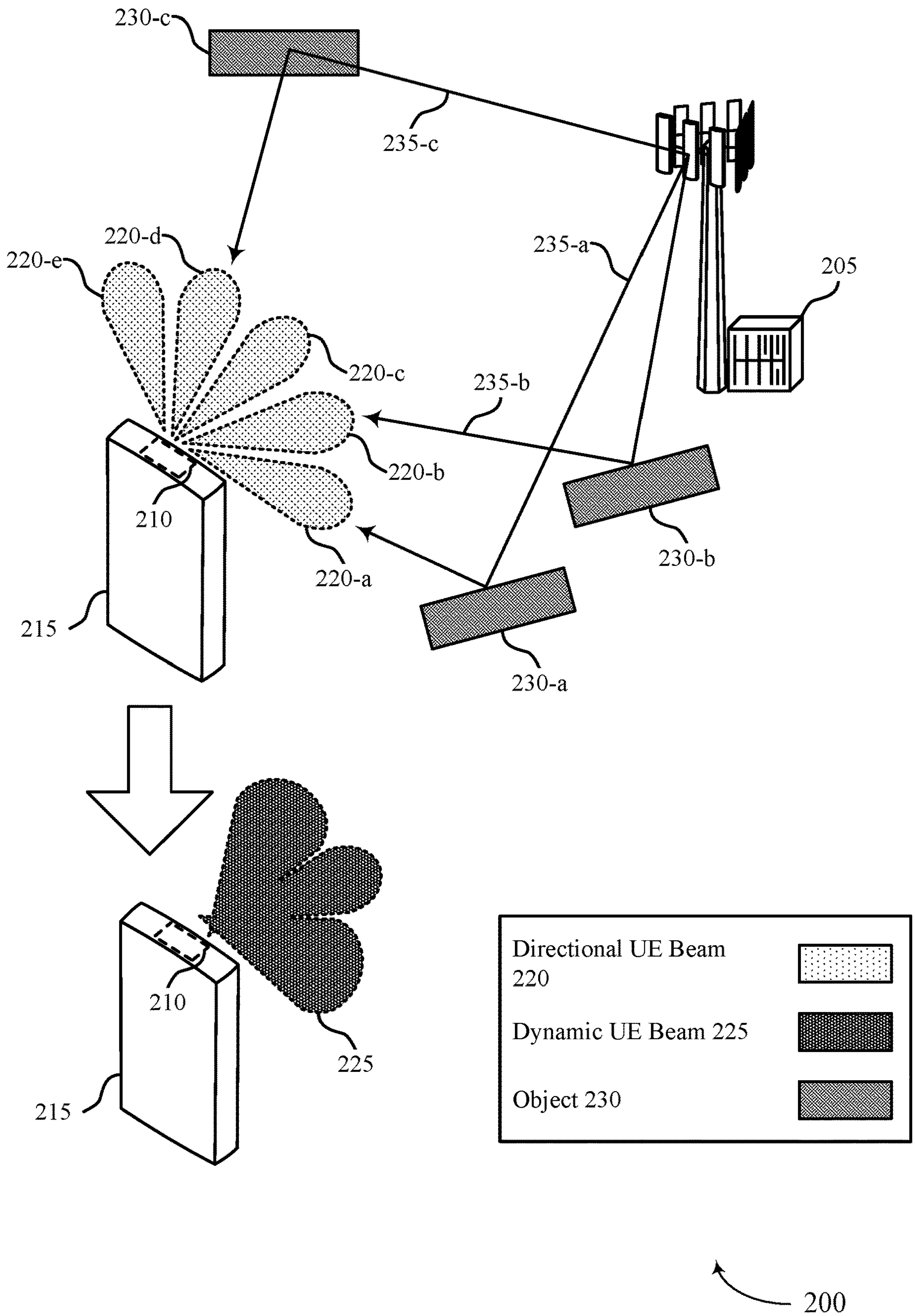
104

FIG. 1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220-c
235-b
220-b
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230-a
210
225
215
Directional UE Beam 220
Dynamic UE Beam 225
Object 230
200

FIG. 2

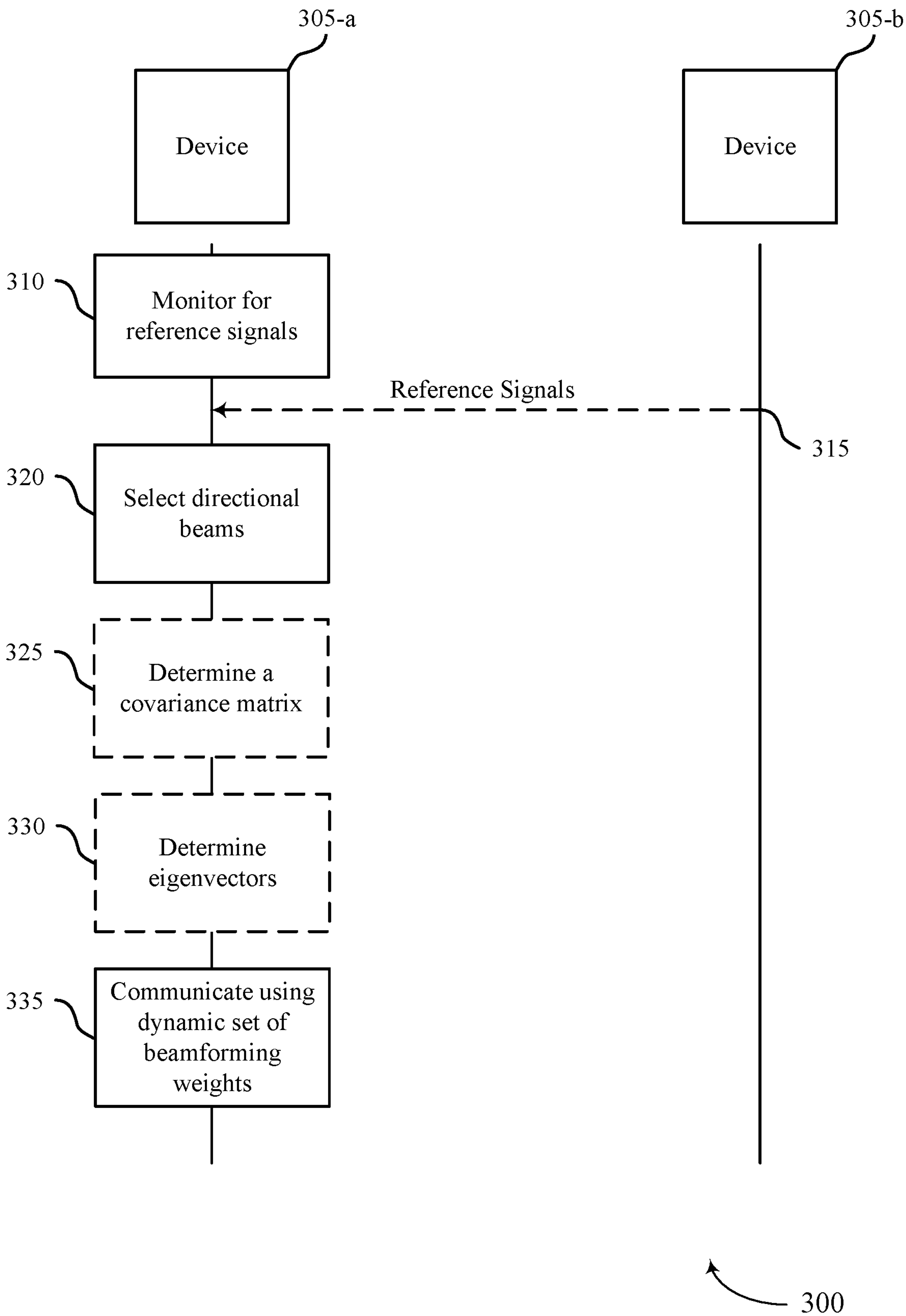
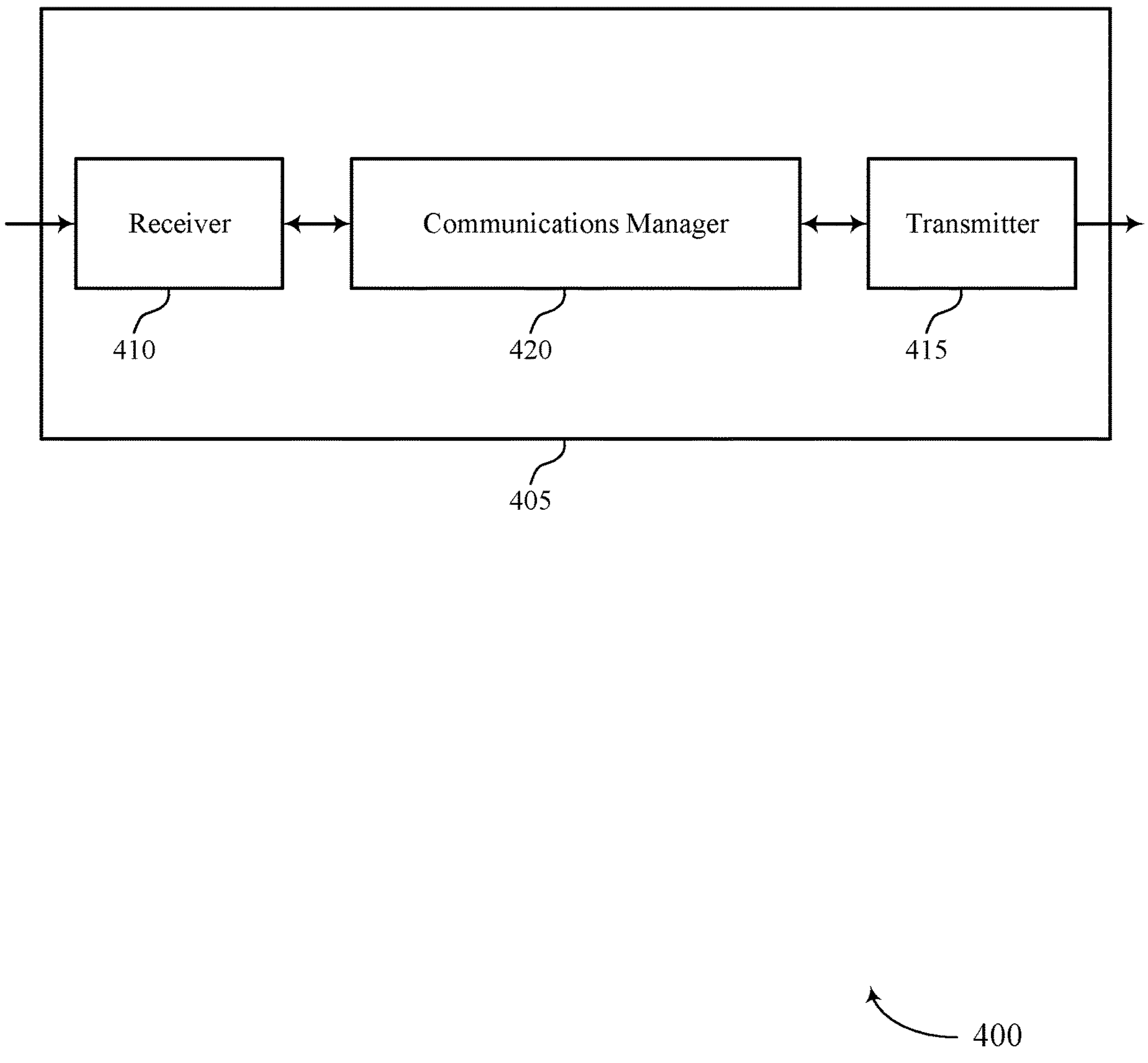

305-a
305-b
Device
Device
310
Monitor for reference signals
Reference Signals
315
320
Select directional beams
325
Determine a covariance matrix
330
Determine eigenvectors
335
Communicate using dynamic set of beamforming weights
300

FIG. 3



Receiver
Communications Manager
Transmitter
410
420
415
405
400

FIG. 4

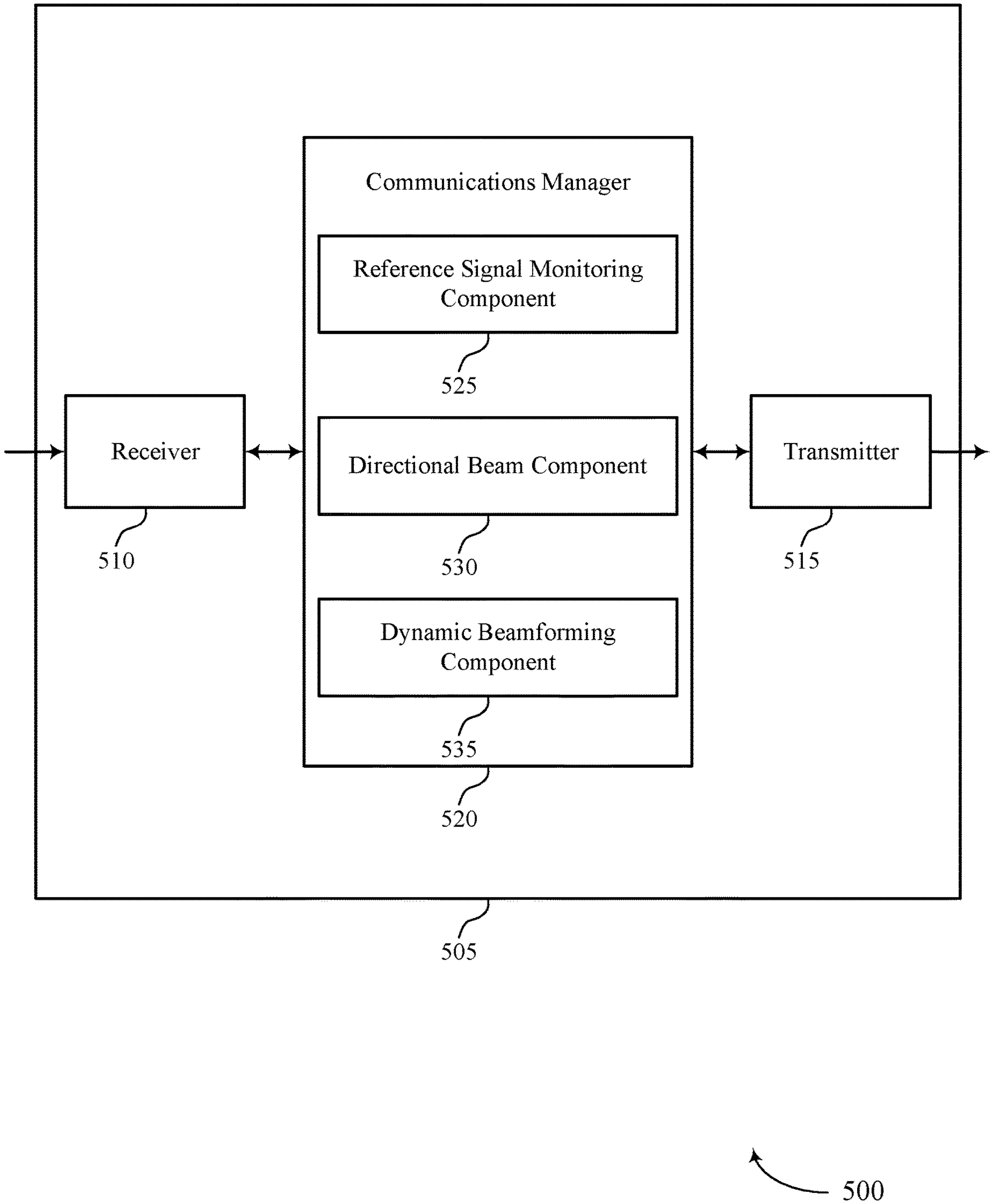
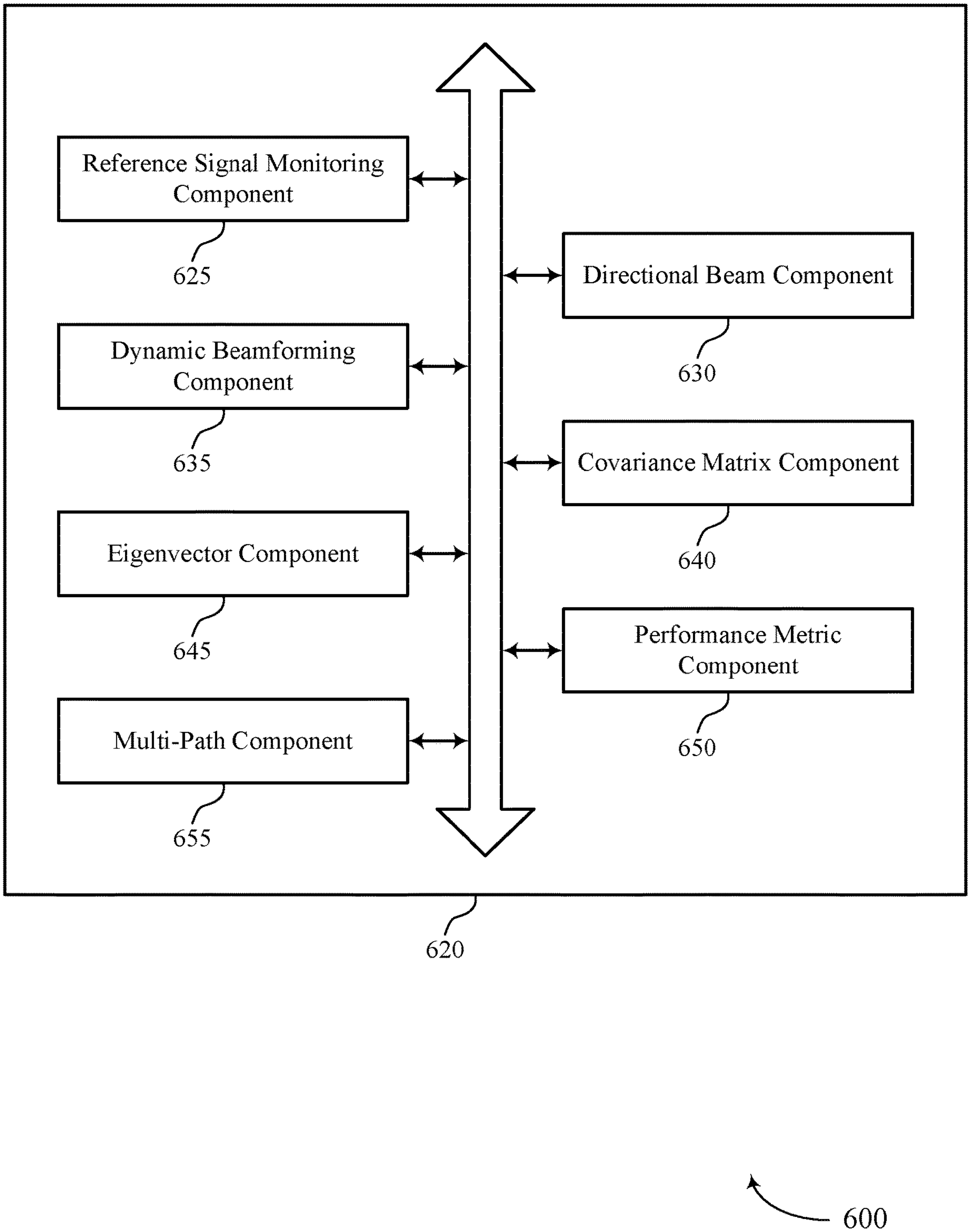

Communications Manager
Reference Signal Monitoring Component
525
Receiver
Directional Beam Component
Transmitter
510
530
515
Dynamic Beamforming Component
535
520
505
500

FIG. 5



Reference Signal Monitoring Component
625
Directional Beam Component
630
Dynamic Beamforming Component
635
Covariance Matrix Component
640
Eigenvector Component
645
Performance Metric Component
650
Multi-Path Component
655
620
600

FIG. 6

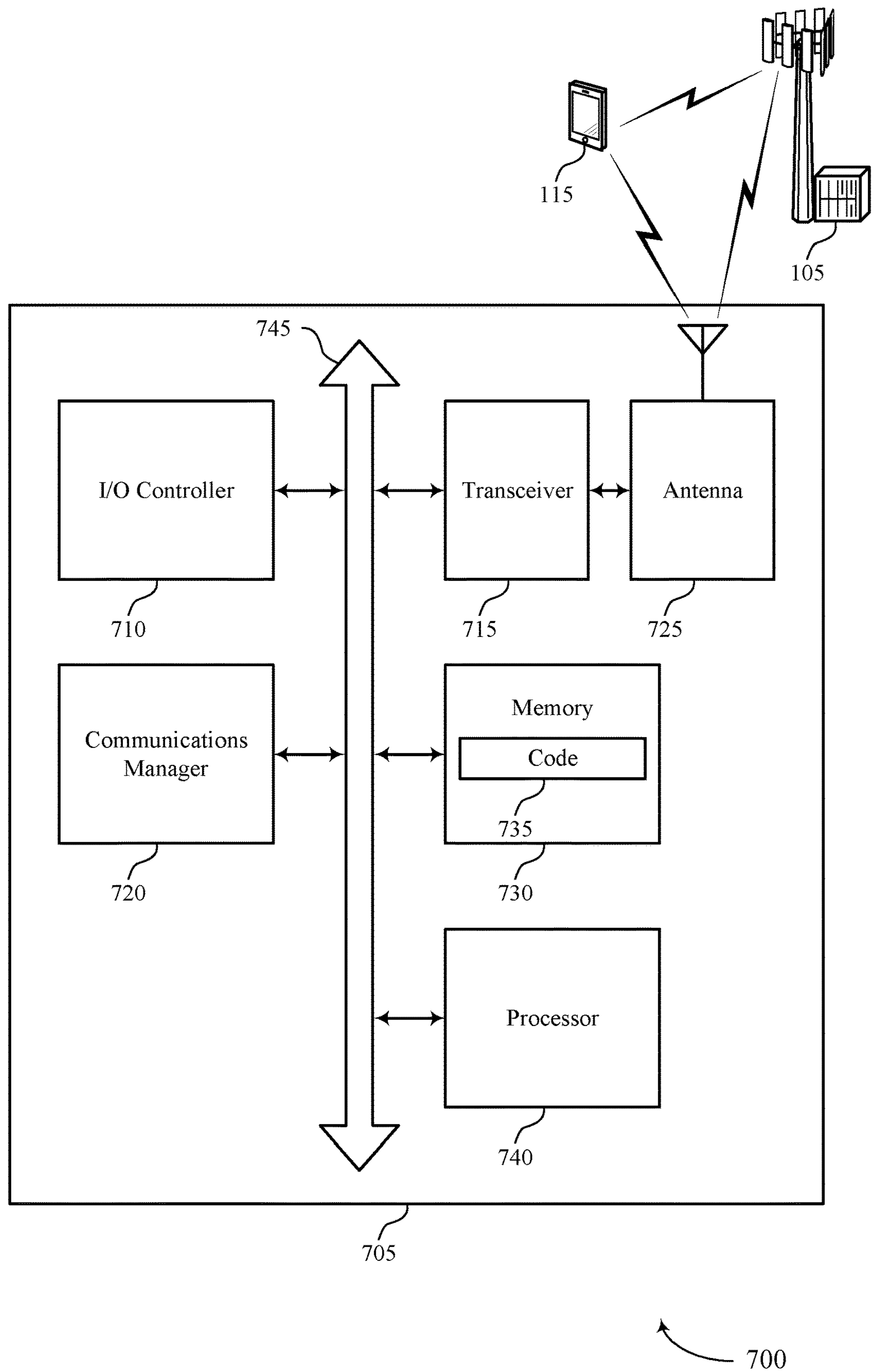

115
105
745
I/O Controller
Transceiver
Antenna
710
715
725
Communications Manager
Memory
Code
735
720
730
Processor
740
705
700

FIG. 7

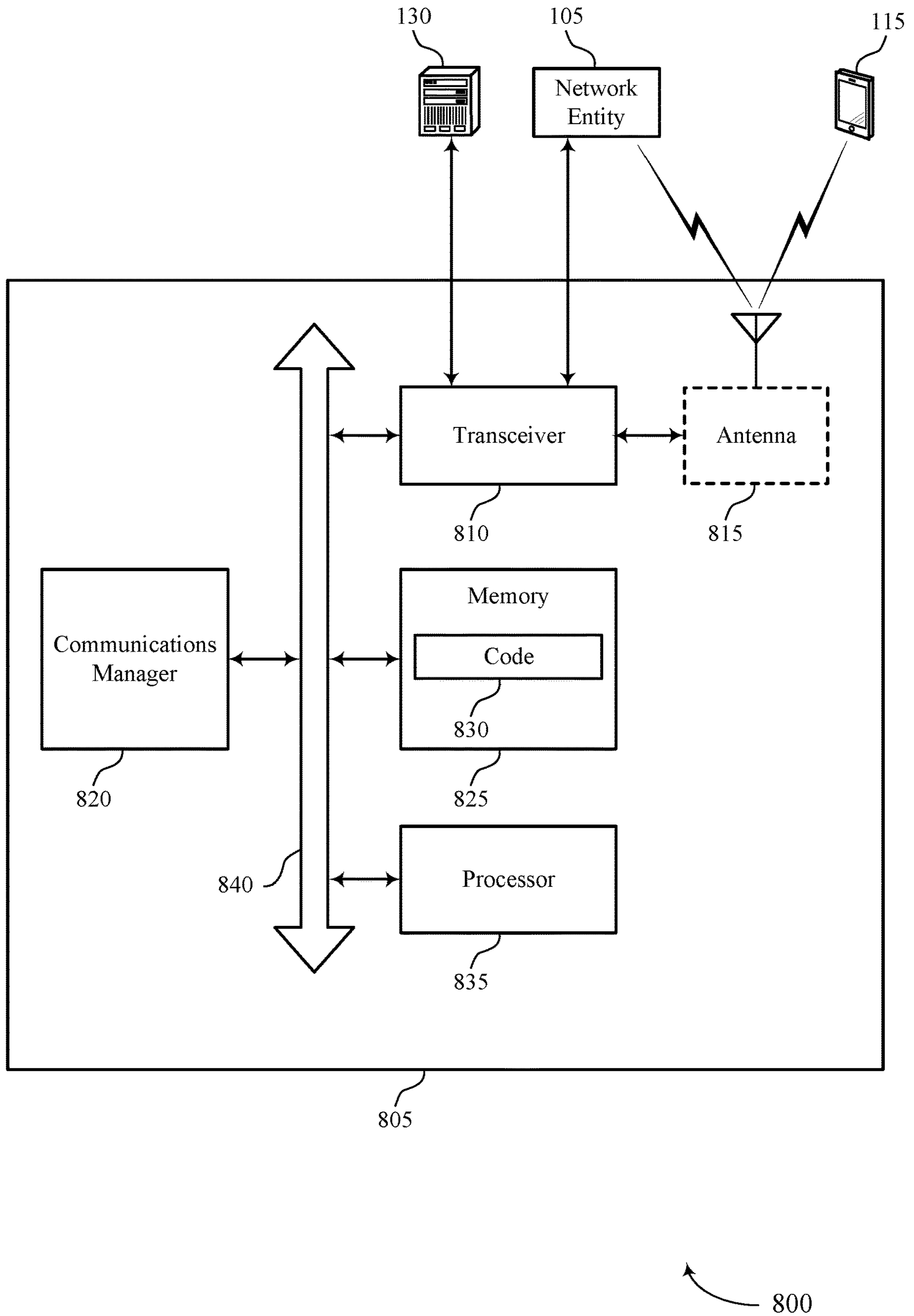

130
105
Network Entity
115
Transceiver
Antenna
810
815
Memory
Code
Communications Manager
830
820
825
840
Processor
835
805
800

FIG. 8

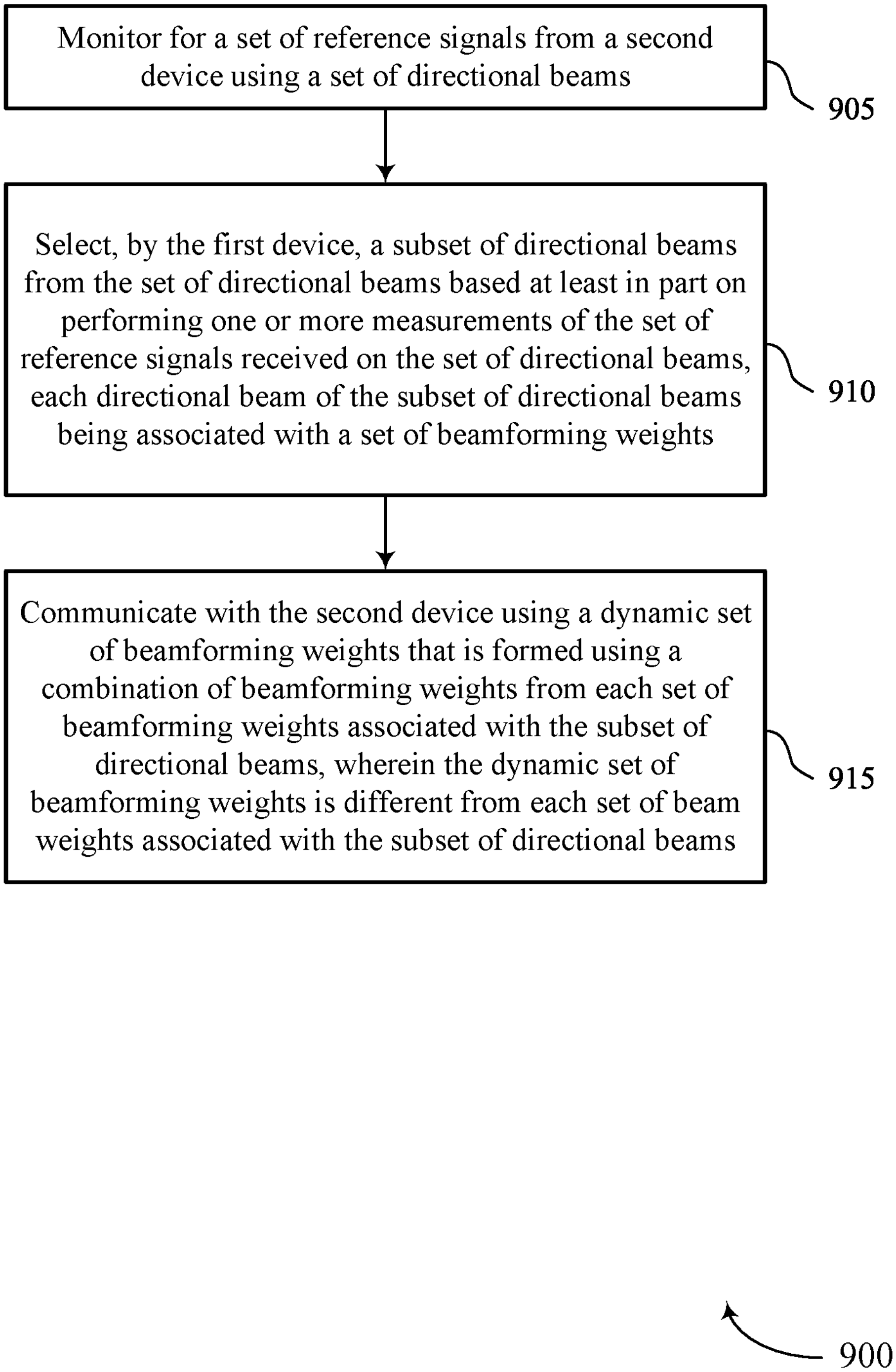

Monitor for a set of reference signals from a second device using a set of directional beams
905
Select, by the first device, a subset of directional beams from the set of directional beams based at least in part on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights
910
Communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, wherein the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams
915
900

FIG. 9

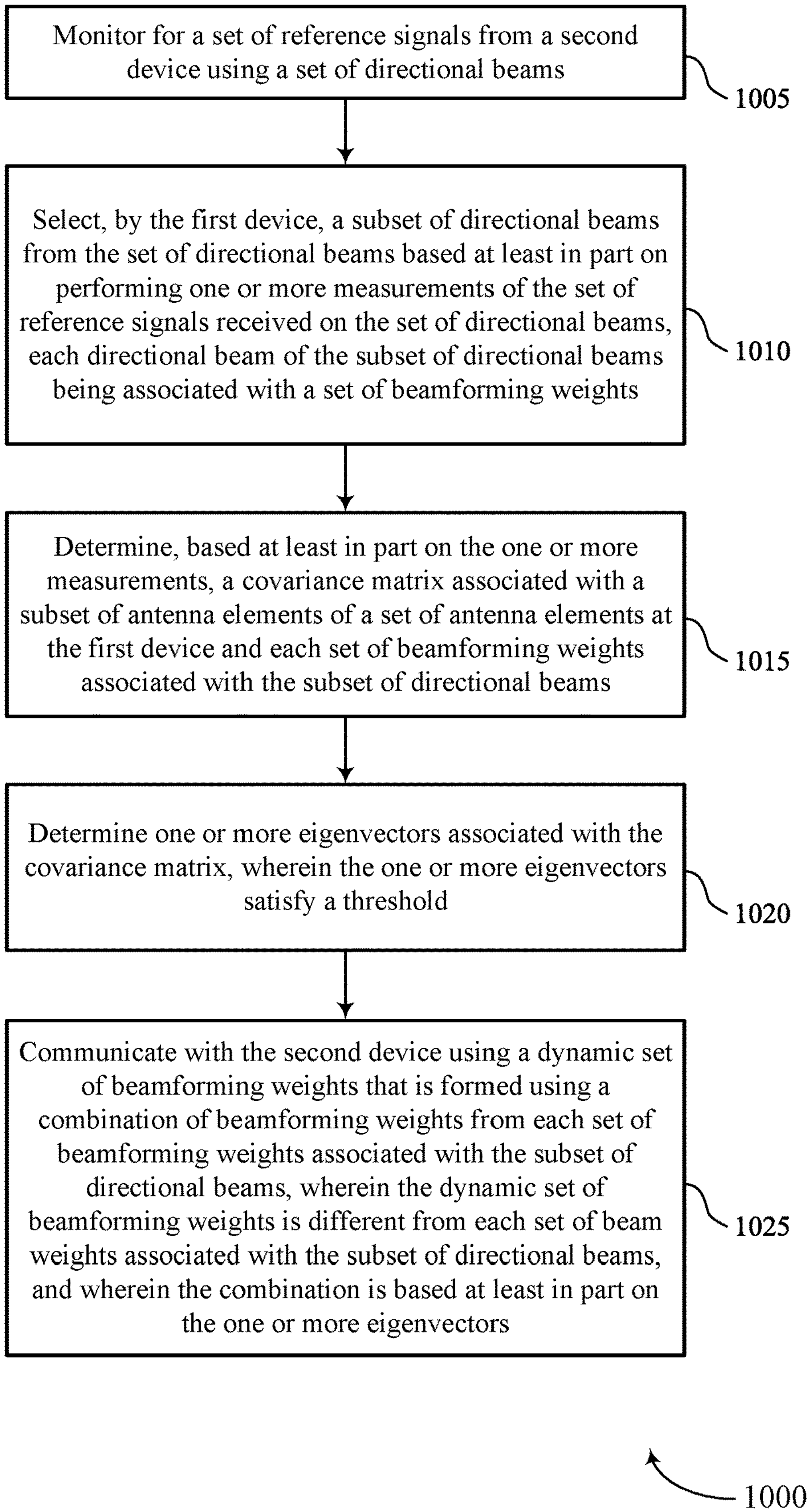

Monitor for a set of reference signals from a second device using a set of directional beams
1005
Select, by the first device, a subset of directional beams from the set of directional beams based at least in part on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights
1010
Determine, based at least in part on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of directional beams
1015
Determine one or more eigenvectors associated with the covariance matrix, wherein the one or more eigenvectors satisfy a threshold
1020
Communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, wherein the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams, and wherein the combination is based at least in part on the one or more eigenvectors
1025
1000

FIG. 10

METHODS FOR DYNAMIC BEAMFORMING WEIGHT CONSTRUCTION BASED ON DIRECTIONAL MEASUREMENTS

FIELD OF TECHNOLOGY

The following relates to wireless communications, including methods for dynamic beamforming weight construction based on directional measurements.

BACKGROUND

Wireless communications systems are widely deployed to provide various types of communication content such as voice, video, packet data, messaging, broadcast, and so on. These systems may be capable of supporting communication with multiple users by sharing the available system resources (e.g., time, frequency, and power). Examples of such multiple-access systems include fourth generation (4G) systems such as Long Term Evolution (LTE) systems, LTE-Advanced (LTE-A) systems, or LTE-A Pro systems, and fifth generation (5G) systems which may be referred to as New Radio (NR) systems. These systems may employ technologies such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), or discrete Fourier transform spread orthogonal frequency division multiplexing (DFT-S-OFDM).

A wireless multiple-access communications system may include one or more base stations or one or more network access nodes, each simultaneously supporting communication for multiple communication devices, which may be otherwise known as user equipment (UE). Some wireless communication devices (e.g., base stations, UEs) may support beamforming operations in which multiple antennas are used to generate directional beams for transmitting and receiving communications. Wireless communication devices may, in some cases, use a codebook to determine beamforming weights for generating directional beams.

SUMMARY

The described techniques relate to improved methods, systems, devices, and apparatuses that support methods for dynamic beamforming weight construction based on directional measurements. Generally, a first device may monitor for a set of reference signals from a second device using a set of directional beams. The first device may perform measurements on the received reference signals and select a subset of directional beams from the set of directional beams based on the performed measurements. Each directional beam may be associated with a set of beamforming weights (e.g., based on a beamforming codebook). The first device may communicate with the second device using a dynamic set of beamforming weights. The dynamic set of beamforming weights may be different from each set of beamforming weights associated with the subset of directional beams. For example, the first device may form the dynamic set of beamforming weights using a combination of beamforming weights associated with the subset of directional beams. Using a directional beam that is based on the dynamic set of beamforming weights, the first device may reduce processing and power consumption while improving performance and throughput when communicating with (e.g., transmitting messages to, receiving messages from) the second device.

A method for wireless communication at a first device is described. The method may include monitoring for a set of reference signals from a second device using a set of directional beams, selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights, and communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams.

An apparatus for wireless communication at a first device is described. The apparatus may include a processor, memory coupled with the processor, and instructions stored in the memory. The instructions may be executable by the processor to cause the apparatus to monitor for a set of reference signals from a second device using a set of directional beams, select, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights, and communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams.

Another apparatus for wireless communication at a first device is described. The apparatus may include means for monitoring for a set of reference signals from a second device using a set of directional beams, means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights, and means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams.

A non-transitory computer-readable medium storing code for wireless communication at a first device is described. The code may include instructions executable by a processor to monitor for a set of reference signals from a second device using a set of directional beams, select, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights, and communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining, based on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of directional beams and determining one or more eigenvectors associated with the covariance matrix, where the one or more eigenvectors satisfy a threshold, and where the combination may be based on the one or more eigenvectors.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for generating each directional beam of the set of directional beams based on a respective set of beamforming weights, where each respective set of beamforming weights corresponds to a direction of a set of multiple directions, and where receiving the set of reference signals using the set of directional beams may be based on generating each directional beam.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, each beamforming weight of the respective set of beamforming weights includes a weighting applied to an antenna element of a subset of antenna elements at the first device.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, each reference signal of the set of reference signals excites a multi-path component of a set of multi-path components, each multi-path component including a respective signal path between the first device and the second device.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining an angle of arrival associated with each multi-path component of the set of multi-path components, where selecting the subset of directional beams may be based on the angle of arrival associated with each multi-path component of the set of multi-path components.

Some examples of the method, apparatuses, and non-transitory computer-readable medium described herein may further include operations, features, means, or instructions for determining a performance metric associated with communications between the first device and the second device, where a number of directional beams including the subset of directional beams may be based on the performance metric.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the performance metric includes a link budget, an effective spectral efficiency, a block error rate (BLER), a signal-to-interference-plus-noise ratio (SINR), a signal-to-noise ratio (SNR), or a reference signal received power (RSRP) ratio.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, selecting the subset of directional beams may include operations, features, means, or instructions for determining, based on the one or more measurements, one or more directional beams of the set of directional beams that satisfy a threshold, where the subset of directional beams includes the one or more directional beams that satisfy the threshold.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first device includes a network entity and each reference signal of the set of reference signals includes a sounding reference signal (SRS).

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first device includes a user equipment and each reference signal of the set of reference signals includes a synchronization signal block (SSB), a channel state information reference signal (CSI-RS), or a demodulation reference signal (DMRS), or any combination thereof.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the one or more measurements include one or more RSRP measurements or one or more SINR measurements.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the combination may be based on maximum ratio combining, or equal gain combining, or one or more optimum combining strategies, or any combination thereof.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first device includes a user equipment (UE) and each reference signal of the set of reference signals may be transmitted using one or more millimeter wave (mmW) carrier frequencies.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the one or more mmW carrier frequencies may be greater than about 24.25 gigahertz.

In some examples of the method, apparatuses, and non-transitory computer-readable medium described herein, the first device includes a network entity and each reference signal of the set of reference signals may be transmitted using one or more carrier frequencies.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** and **2** each illustrate an example of a wireless communications system that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

FIG. **3** illustrates an example of a process flow in a system that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

FIGS. **4** and **5** show block diagrams of devices that support methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

FIG. **6** shows a block diagram of a communications manager that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

FIG. **7** shows a diagram of a system including a device that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

FIG. **8** shows a diagram of a system including a device that supports methods for dynamic beam construction based on directional measurements in accordance with aspects of the present disclosure.

FIGS. **9** and **10** show flowcharts illustrating methods that support methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

In some wireless communications systems, such as systems that support millimeter wave (mmW) communications (e.g., new radio (NR) systems), wireless communication devices (e.g., network entities, transmission/reception points (TRPs), user equipments (UEs)) may communicate via directional transmissions (e.g., beams). For example, communications between communications devices operating within a wireless communications system may be carried out via beamforming. In such cases, some wireless communication devices (e.g., the network entities and the UEs) may support beamforming operations in which antenna elements (e.g., of an antenna array) may be used to generate directional beams for transmitting or receiving communications. In some examples, a first communication device may apply a respective phase and amplitude (e.g., weight) to each of multiple antenna elements (e.g., of an antenna array) to generate a beam in a particular direction for communications with a second communication device. That is, the first device may determine a suitable combination of antenna weights to apply to a set of antenna elements for generating a beam in a particular direction.

As the number of antennas (e.g., antenna elements) at the communication device increases, for example, to satisfy a link budget for communications within a mmW communications system, the number of possible antenna weight combinations (e.g., the number of directions in which a beam may be generated) may also increase. As a result, processing and power consumption at the first communication device may also increase. Moreover, channel conditions may change relatively frequently (e.g., on the order of milliseconds (ms)) and, as such, the direction (e.g., and corresponding antenna weight combination) for communications with the second device may also change. Therefore, rather than determining (e.g., calculating) a suitable antenna weight combination, the communication device may select an antenna weight combination (e.g., a beamforming direction) from a predefined codebook. For example, the first device may select a suitable antenna weight combination based on channel information obtained from reference signal measurements. However, the number of beamforming weights included in the codebook may be rigid (e.g., due to a capacity of memory storage at the device) and situations may occur in which a suitable beamforming direction may not be available through the weights included in the codebook. Therefore, mechanisms that enable a device to dynamically determine a suitable combination of beamforming weights may be desirable.

As described herein, techniques for constructing a dynamic beam from multiple static (e.g., preconfigured) directional beams may be used to reduce processing and power consumption at a communications device. For example, a first communication device (e.g., the UE or the network entity) may perform beam quality measurements (e.g., reference signal received power (RSRP) measurements, signal-to-interference-plus-noise ratio (SINR) measurements, or the like) on multiple directional beams used for receiving reference signals from a second communication device (e.g., another UE or another network entity). In some examples (e.g., if the second communication device is the network entity), the reference signals may include synchronization signal blocks (SSBs), channel state information reference signals (CSI-RSs), demodulation reference signals (DMRSs), among other examples. In other examples (e.g., if the second communication device is the UE), the reference signals may include sounding reference signals (SRSs), or some other reference signals transmitted by the UE. The first communication device may select a number of directional beams (K) determined to have a relatively high or otherwise acceptable signal strength compared to other measured beams (e.g., where measurements associated with the K directional beams may satisfy a threshold). The first communication device may combine (e.g., via maximum ratio combining) the antenna weights of each selected directional beam to form a dynamic set of beamforming weights (e.g., for generating a dynamic beam) for communications with the second device. In some examples, the dynamic set of beamforming weights may increase the receive power (e.g., or the transmit power) at the first device.

Particular aspects of the subject matter described herein may be implemented to realize one or more potential advantages associated with techniques for constructing a dynamic beam from multiple directional beams using maximum ratio combining. For example, the described techniques may support reduce processing and power consumption while improving performance at the first communication device.

Aspects of the disclosure are initially described in the context of wireless communications systems. Aspects of the disclosure are further illustrated by and described with reference to a process flow, apparatus diagrams, system diagrams, and flowcharts that relate to methods for dynamic beamforming weight construction based on directional measurements.

FIG. **1** illustrates an example of a wireless communications system **100** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with one or more aspects of the present disclosure. The wireless communications system **100** may include one or more network entities **105**, one or more UEs **115**, and a core network **130**. In some examples, the wireless communications system **100** may be a Long Term Evolution (LTE) network, an LTE-Advanced (LTE-A) network, an LTE-A Pro network, a New Radio (NR) network, or a network operating in accordance with other systems and radio technologies, including future systems and radio technologies not explicitly mentioned herein.

The network entities **105** may be dispersed throughout a geographic area to form the wireless communications system **100** and may include devices in different forms or having different capabilities. In various examples, a network entity **105** may be referred to as a network element, a mobility element, a radio access network (RAN) node, or network equipment, among other nomenclature. In some examples, network entities **105** and UEs **115** may wirelessly communicate via one or more communication links **125** (e.g., a radio frequency (RF) access link). For example, a network entity **105** may support a coverage area **110** (e.g., a geographic coverage area) over which the UEs **115** and the network entity **105** may establish one or more communication links **125**. The coverage area **110** may be an example of a geographic area over which a network entity **105** and a UE **115** may support the communication of signals according to one or more radio access technologies (RATs).

The UEs **115** may be dispersed throughout a coverage area **110** of the wireless communications system **100**, and each UE **115** may be stationary, or mobile, or both at different times. The UEs **115** may be devices in different forms or having different capabilities. Some example UEs **115** are illustrated in FIG. **1**. The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115** or network entities **105**, as shown in FIG. **1**.

As described herein, a node of the wireless communications system **100**, which may be referred to as a network node, or a wireless node, may be a network entity **105** (e.g., any network entity described herein), a UE **115** (e.g., any UE described herein), a network controller, an apparatus, a device, a computing system, one or more components, or another suitable processing entity configured to perform any of the techniques described herein. For example, a node may be a UE **115**. As another example, a node may be a network entity **105**. As another example, a first node may be configured to communicate with a second node or a third node. In one aspect of this example, the first node may be a UE **115**, the second node may be a network entity **105**, and the third node may be a UE **115**. In another aspect of this example, the first node may be a UE **115**, the second node may be a network entity **105**, and the third node may be a network entity **105**. In yet other aspects of this example, the first, second, and third nodes may be different relative to these examples. Similarly, reference to a UE **115**, network entity **105**, apparatus, device, computing system, or the like may include disclosure of the UE **115**, network entity **105**, apparatus, device, computing system, or the like being a node. For example, disclosure that a UE **115** is configured to receive information from a network entity **105** also discloses that a first node is configured to receive information from a second node.

In some examples, network entities **105** may communicate with the core network **130**, or with one another, or both. For example, network entities **105** may communicate with the core network **130** via one or more backhaul communication links **120** (e.g., in accordance with an S1, N2, N3, or other interface protocol). In some examples, network entities **105** may communicate with one another over a backhaul communication link **120** (e.g., in accordance with an X2, Xn, or other interface protocol) either directly (e.g., directly between network entities **105**) or indirectly (e.g., via a core network **130**). In some examples, network entities **105** may communicate with one another via a midhaul communication link **162** (e.g., in accordance with a midhaul interface protocol) or a fronthaul communication link **168** (e.g., in accordance with a fronthaul interface protocol), or any combination thereof. The backhaul communication links **120**, midhaul communication links **162**, or fronthaul communication links **168** may be or include one or more wired links (e.g., an electrical link, an optical fiber link), one or more wireless links (e.g., a radio link, a wireless optical link), among other examples or various combinations thereof. A UE **115** may communicate with the core network **130** through a communication link **155**.

One or more of the network entities **105** described herein may include or may be referred to as a base station **140** (e.g., a base transceiver station, a radio base station, an NR base station, an access point, a radio transceiver, a NodeB, an eNodeB (eNB), a next-generation NodeB or a giga-NodeB (either of which may be referred to as a gNB), a 5G NB, a next-generation eNB (ng-eNB), a Home NodeB, a Home eNodeB, or other suitable terminology). In some examples, a network entity **105** (e.g., a base station **140**) may be implemented in an aggregated (e.g., monolithic, standalone) base station architecture, which may be configured to utilize a protocol stack that is physically or logically integrated within a single network entity **105** (e.g., a single RAN node, such as a base station **140**).

In some examples, a network entity **105** may be implemented in a disaggregated architecture (e.g., a disaggregated base station architecture, a disaggregated RAN architecture), which may be configured to utilize a protocol stack that is physically or logically distributed among two or more network entities **105**, such as an integrated access backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity **105** may include one or more of a central unit (CU) **160**, a distributed unit (DU) **165**, a radio unit (RU) **170**, a RAN Intelligent Controller (RIC) **175** (e.g., a Near-Real Time RIC (Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) **180** system, or any combination thereof. An RU **170** may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities **105** in a disaggregated RAN architecture may be co-located, or one or more components of the network entities **105** may be located in distributed locations (e.g., separate physical locations). In some examples, one or more network entities **105** of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

The split of functionality between a CU **160**, a DU **165**, and an RU **175** is flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, RF functions, and any combinations thereof) are performed at a CU **160**, a DU **165**, or an RU **175**. For example, a functional split of a protocol stack may be employed between a CU **160** and a DU **165** such that the CU **160** may support one or more layers of the protocol stack and the DU **165** may support one or more different layers of the protocol stack. In some examples, the CU **160** may host upper protocol layer (e.g., layer 3 (L3), layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaption protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU **160** may be connected to one or more DUs **165** or RUs **170**, and the one or more DUs **165** or RUs **170** may host lower protocol layers, such as layer 1 (L1) (e.g., physical (PHY) layer) or L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU **160**. Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU **165** and an RU **170** such that the DU **165** may support one or more layers of the protocol stack and the RU **170** may support one or more different layers of the protocol stack. The DU **165** may support one or multiple different cells (e.g., via one or more RUs **170**). In some cases, a functional split between a CU **160** and a DU **165**, or between a DU **165** and an RU **170** may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU **160**, a DU **165**, or an RU **170**, while other functions of the protocol layer are performed by a different one of the CU **160**, the DU **165**, or the RU **170**). A CU **160** may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU **160** may be connected to one or more DUs **165** via a midhaul communication link **162** (e.g., F1, F1-c, F1-u), and a DU **165** may be connected to one or more RUs **170** via a fronthaul communication link **168** (e.g., open fronthaul (FH) interface). In some examples, a midhaul communication link **162** or a fronthaul communication link **168** may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities **105** that are in communication over such communication links.

In wireless communications systems (e.g., wireless communications system **100**), infrastructure and spectral resources for radio access may support wireless backhaul link capabilities to supplement wired backhaul connections, providing an IAB network architecture (e.g., to a core network **130**). In some cases, in an IAB network, one or more network entities **105** (e.g., IAB nodes **104**) may be partially controlled by each other. One or more IAB nodes **104** may be referred to as a donor entity or an IAB donor. One or more DUs **165** or one or more RUs **170** may be partially controlled by one or more CUs **160** associated with a donor network entity **105** (e.g., a donor base station **140**). The one or more donor network entities **105** (e.g., IAB donors) may be in communication with one or more additional network entities **105** (e.g., IAB nodes **104**) via supported access and backhaul links (e.g., backhaul communication links **120**). IAB nodes **104** may include an IAB mobile termination (IAB-MT) controlled (e.g., scheduled) by DUs **165** of a coupled IAB donor. An IAB-MT may include an independent set of antennas for relay of communications with UEs **115**, or may share the same antennas (e.g., of an RU **170**) of an IAB node **104** used for access via the DU **165** of the IAB node **104** (e.g., referred to as virtual IAB-MT (vIAB-MT)). In some examples, the IAB nodes **104** may include DUs **165** that support communication links with additional entities (e.g., IAB nodes **104**, UEs **115**) within the relay chain or configuration of the access network (e.g., downstream). In such cases, one or more components of the disaggregated RAN architecture (e.g., one or more IAB nodes **104** or components of IAB nodes **104**) may be configured to operate according to the techniques described herein.

For instance, an access network (AN) or RAN may include communications between access nodes (e.g., an IAB donor), IAB nodes **104**, and one or more UEs **115**. The IAB donor may facilitate connection between the core network **130** and the AN (e.g., via a wired or wireless connection to the core network **130**). That is, an IAB donor may refer to a RAN node with a wired or wireless connection to core network **130**. The IAB donor may include a CU **160** and at least one DU **165** (e.g., and RU **170**), in which case the CU **160** may communicate with the core network **130** over an interface (e.g., a backhaul link). IAB donor and IAB nodes **104** may communicate over an F1 interface according to a protocol that defines signaling messages (e.g., an F1 AP protocol). Additionally, or alternatively, the CU **160** may communicate with the core network over an interface, which may be an example of a portion of backhaul link, and may communicate with other CUs **160** (e.g., a CU **160** associated with an alternative IAB donor) over an Xn-C interface, which may be an example of a portion of a backhaul link.

An IAB node **104** may refer to a RAN node that provides IAB functionality (e.g., access for UEs **115**, wireless self-backhauling capabilities). A DU **165** may act as a distributed scheduling node towards child nodes associated with the IAB node **104**, and the IAB-MT may act as a scheduled node towards parent nodes associated with the IAB node **104**. That is, an IAB donor may be referred to as a parent node in communication with one or more child nodes (e.g., an IAB donor may relay transmissions for UEs through one or more other IAB nodes **104**). Additionally, or alternatively, an IAB node **104** may also be referred to as a parent node or a child node to other IAB nodes **104**, depending on the relay chain or configuration of the AN. Therefore, the IAB-MT entity of IAB nodes **104** may provide a Uu interface for a child IAB node **104** to receive signaling from a parent IAB node **104**, and the DU interface (e.g., DUs **165**) may provide a Uu interface for a parent IAB node **104** to signal to a child IAB node **104** or UE **115**.

For example, IAB node **104** may be referred to as a parent node that supports communications for a child IAB node, and referred to as a child IAB node associated with an IAB donor. The IAB donor may include a CU **160** with a wired or wireless connection (e.g., a backhaul communication link **120**) to the core network **130** and may act as parent node to IAB nodes **104**. For example, the DU **165** of IAB donor may relay transmissions to UEs **115** through IAB nodes **104**, and may directly signal transmissions to a UE **115**. The CU **160** of IAB donor may signal communication link establishment via an F1 interface to IAB nodes **104**, and the IAB nodes **104** may schedule transmissions (e.g., transmissions to the UEs **115** relayed from the IAB donor) through the DUs **165**. That is, data may be relayed to and from IAB nodes **104** via signaling over an NR Uu interface to MT of the IAB node **104**. Communications with IAB node **104** may be scheduled by a DU **165** of IAB donor and communications with IAB node **104** may be scheduled by DU **165** of IAB node **104**.

In the case of the techniques described herein applied in the context of a disaggregated RAN architecture, one or more components of the disaggregated RAN architecture may be configured to support methods for dynamic beam construction based on directional measurements as described herein. For example, some operations described as being performed by a UE **115** or a network entity **105** (e.g., a base station **140**) may additionally, or alternatively, be performed by one or more components of the disaggregated RAN architecture (e.g., IAB nodes **104**, DUs **165**, CUs **160**, RUs **170**, RIC **175**, SMO **180**).

A UE **115** may include or may be referred to as a mobile device, a wireless device, a remote device, a handheld device, or a subscriber device, or some other suitable terminology, where the "device" may also be referred to as a unit, a station, a terminal, or a client, among other examples. A UE **115** may also include or may be referred to as a personal electronic device such as a cellular phone, a personal digital assistant (PDA), a tablet computer, a laptop computer, or a personal computer. In some examples, a UE **115** may include or be referred to as a wireless local loop (WLL) station, an Internet of Things (IoT) device, an Internet of Everything (IoE) device, or a machine type communications (MTC) device, among other examples, which may be implemented in various objects such as appliances, or vehicles, meters, among other examples.

The UEs **115** described herein may be able to communicate with various types of devices, such as other UEs **115** that may sometimes act as relays as well as the network entities **105** and the network equipment including macro eNBs or gNBs, small cell eNBs or gNBs, or relay base stations, among other examples, as shown in FIG. **1**.

The UEs **115** and the network entities **105** may wirelessly communicate with one another via one or more communication links **125** (e.g., an access link) over one or more carriers. The term "carrier" may refer to a set of RF spectrum resources having a defined physical layer structure for supporting the communication links **125**. For example, a carrier used for a communication link **125** may include a portion of a RF spectrum band (e.g., a bandwidth part (BWP)) that is operated according to one or more physical layer channels for a given radio access technology (e.g., LTE, LTE-A, LTE-A Pro, NR). Each physical layer channel may carry acquisition signaling (e.g., synchronization signals, system information), control signaling that coordinates operation for the carrier, user data, or other signaling. The wireless communications system **100** may support communication with a UE **115** using carrier aggregation or multi-carrier operation. A UE **115** may be configured with multiple downlink component carriers and one or more uplink component carriers according to a carrier aggregation configuration. Carrier aggregation may be used with both frequency division duplexing (FDD) and time division duplexing (TDD) component carriers. Communication between a network entity **105** and other devices may refer to communication between the devices and any portion (e.g., entity, sub-entity) of a network entity **105**. For example, the terms "transmitting," "receiving," or "communicating," when referring to a network entity **105**, may refer to any portion of a network entity **105** (e.g., a base station **140**, a CU **160**, a DU **165**, a RU **170**) of a RAN communicating with another device (e.g., directly or via one or more other network entities **105**).

Signal waveforms transmitted over a carrier may be made up of multiple subcarriers (e.g., using multi-carrier modulation (MCM) techniques such as orthogonal frequency division multiplexing (OFDM) or discrete Fourier transform spread OFDM (DFT-S-OFDM)). In a system employing MCM techniques, a resource element may refer to resources of one symbol period (e.g., a duration of one modulation symbol) and one subcarrier, in which case the symbol period and subcarrier spacing may be inversely related. The quantity of bits carried by each resource element may depend on the modulation scheme (e.g., the order of the modulation scheme, the coding rate of the modulation scheme, or both) such that the more resource elements that a device receives and the higher the order of the modulation scheme, the higher the data rate may be for the device. A wireless communications resource may refer to a combination of an RF spectrum resource, a time resource, and a spatial resource (e.g., a spatial layer, a beam), and the use of multiple spatial resources may increase the data rate or data integrity for communications with a UE **115**.

The time intervals for the network entities **105** or the UEs **115** may be expressed in multiples of a basic time unit which may, for example, refer to a sampling period of $T_s=1/(\Delta f_{max}\cdot N_f)$ seconds, where Δf_{max} may represent the maximum supported subcarrier spacing, and N_f may represent the maximum supported discrete Fourier transform (DFT) size. Time intervals of a communications resource may be organized according to radio frames each having a specified duration (e.g., 10 milliseconds (ms)). Each radio frame may be identified by a system frame number (SFN) (e.g., ranging from 0 to 1023).

Each frame may include multiple consecutively numbered subframes or slots, and each subframe or slot may have the same duration. In some examples, a frame may be divided (e.g., in the time domain) into subframes, and each subframe may be further divided into a quantity of slots. Alternatively, each frame may include a variable quantity of slots, and the quantity of slots may depend on subcarrier spacing. Each slot may include a quantity of symbol periods (e.g., depending on the length of the cyclic prefix prepended to each symbol period). In some wireless communications systems **100**, a slot may further be divided into multiple mini-slots containing one or more symbols. Excluding the cyclic prefix, each symbol period may contain one or more (e.g., N_f) sampling periods. The duration of a symbol period may depend on the subcarrier spacing or frequency band of operation.

A subframe, a slot, a mini-slot, or a symbol may be the smallest scheduling unit (e.g., in the time domain) of the wireless communications system **100** and may be referred to as a transmission time interval (TTI). In some examples, the TTI duration (e.g., a quantity of symbol periods in a TTI) may be variable. Additionally, or alternatively, the smallest scheduling unit of the wireless communications system **100** may be dynamically selected (e.g., in bursts of shortened TTIs (sTTIs)).

Physical channels may be multiplexed on a carrier according to various techniques. A physical control channel and a physical data channel may be multiplexed on a downlink carrier, for example, using one or more of time division multiplexing (TDM) techniques, frequency division multiplexing (FDM) techniques, or hybrid TDM-FDM techniques. A control region (e.g., a control resource set (CORESET)) for a physical control channel may be defined by a set of symbol periods and may extend across the system bandwidth or a subset of the system bandwidth of the carrier. One or more control regions (e.g., CORESETs) may be configured for a set of the UEs **115**. For example, one or more of the UEs **115** may monitor or search control regions for control information according to one or more search space sets, and each search space set may include one or multiple control channel candidates in one or more aggregation levels arranged in a cascaded manner. An aggregation level for a control channel candidate may refer to an amount of control channel resources (e.g., control channel elements (CCEs)) associated with encoded information for a control information format having a given payload size. Search space sets may include common search space sets configured for sending control information to multiple UEs **115** and UE-specific search space sets for sending control information to a specific UE **115**.

In some examples, a base station **140**), as compared with a macro cell, and a small cell may operate in the same or different (e.g., licensed, unlicensed) frequency bands as macro cells. Small cells may provide unrestricted access to the UEs **115** with service subscriptions with the network provider or may provide restricted access to the UEs **115** having an association with the small cell (e.g., the UEs **115** in a closed subscriber group (CSG), the UEs **115** associated with users in a home or office). A network entity **105** may support one or multiple cells and may also support communications over the one or more cells using one or multiple component carriers.

In some examples, a carrier may support multiple cells, and different cells may be configured according to different protocol types (e.g., MTC, narrowband IoT (NB-IoT), enhanced mobile broadband (eMBB)) that may provide access for different types of devices.

In some examples, a network entity **105** (e.g., a base station **140**, an RU **170**) may be movable and therefore provide communication coverage for a moving coverage area **110**. In some examples, different coverage areas **110** associated with different technologies may overlap, but the different coverage areas **110** may be supported by the same network entity **105**. In some other examples, the overlapping coverage areas **110** associated with different technologies may be supported by different network entities **105**. The wireless communications system **100** may include, for example, a heterogeneous network in which different types of the network entities **105** provide coverage for various coverage areas **110** using the same or different radio access technologies.

The wireless communications system **100** may support synchronous or asynchronous operation. For synchronous operation, network entities **105** (e.g., base stations **140**) may have similar frame timings, and transmissions from different network entities **105** may be approximately aligned in time. For asynchronous operation, network entities **105** may have different frame timings, and transmissions from different network entities **105** may, in some examples, not be aligned in time. The techniques described herein may be used for either synchronous or asynchronous operations.

Some UEs **115**, such as MTC or IoT devices, may be low cost or low complexity devices and may provide for automated communication between machines (e.g., via Machine-to-Machine (M2M) communication). M2M communication or MTC may refer to data communication technologies that allow devices to communicate with one another or a network entity **105** (e.g., a base station **140**) without human intervention. In some examples, M2M communication or MTC may include communications from devices that integrate sensors or meters to measure or capture information and relay such information to a central server or application program that makes use of the information or presents the information to humans interacting with the application program. Some UEs **115** may be designed to collect information or enable automated behavior of machines or other devices. Examples of applications for MTC devices include smart metering, inventory monitoring, water level monitoring, equipment monitoring, healthcare monitoring, wildlife monitoring, weather and geological event monitoring, fleet management and tracking, remote security sensing, physical access control, and transaction-based business charging.

Some UEs **115** may be configured to employ operating modes that reduce power consumption, such as half-duplex communications (e.g., a mode that supports one-way communication via transmission or reception, but not transmission and reception concurrently). In some examples, half-duplex communications may be performed at a reduced peak rate. Other power conservation techniques for the UEs **115** include entering a power saving deep sleep mode when not engaging in active communications, operating over a limited bandwidth (e.g., according to narrowband communications), or a combination of these techniques. For example, some UEs **115** may be configured for operation using a narrowband protocol type that is associated with a defined portion or range (e.g., set of subcarriers or resource blocks (RBs)) within a carrier, within a guard-band of a carrier, or outside of a carrier.

The wireless communications system **100** may be configured to support ultra-reliable communications or low-latency communications, or various combinations thereof. For example, the wireless communications system **100** may be configured to support ultra-reliable low-latency communications (URLLC). The UEs **115** may be designed to support ultra-reliable, low-latency, or critical functions. Ultra-reliable communications may include private communication or group communication and may be supported by one or more services such as push-to-talk, video, or data. Support for ultra-reliable, low-latency functions may include prioritization of services, and such services may be used for public safety or general commercial applications. The terms ultra-reliable, low-latency, and ultra-reliable low-latency may be used interchangeably herein.

In some examples, a UE **115** may be able to communicate directly with other UEs **115** over a device-to-device (D2D) communication link **135** (e.g., in accordance with a peer-to-peer (P2P), D2D, or sidelink protocol). In some examples, one or more UEs **115** of a group that are performing D2D communications may be within the coverage area **110** of a network entity **105** (e.g., a base station **140**, an RU **170**), which may support aspects of such D2D communications being configured by or scheduled by the network entity **105**. In some examples, one or more UEs **115** in such a group may be outside the coverage area **110** of a network entity **105** or may be otherwise unable to or not configured to receive transmissions from a network entity **105**. In some examples, groups of the UEs **115** communicating via D2D communications may support a one-to-many (1:M) system in which each UE **115** transmits to each of the other UEs **115** in the group. In some examples, a network entity **105** may facilitate the scheduling of resources for D2D communications. In some other examples, D2D communications may be carried out between the UEs **115** without the involvement of a network entity **105**.

The core network **130** may provide user authentication, access authorization, tracking, Internet Protocol (IP) connectivity, and other access, routing, or mobility functions. The core network **130** may be an evolved packet core (EPC) or 5G core (5GC), which may include at least one control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management function (AMF)) and at least one user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). The control plane entity may manage non-access stratum (NAS) functions such as mobility, authentication, and bearer management for the UEs **115** served by the network entities **105** (e.g., base stations **140**) associated with the core network **130**. User IP packets may be transferred through the user plane entity, which may provide IP address allocation as well as other functions. The user plane entity may be connected to IP services **150** for one or more network operators. The IP services **150** may include access to the Internet, Intranet(s), an IP Multimedia Subsystem (IMS), or a Packet-Switched Streaming Service.

The wireless communications system **100** may operate using one or more frequency bands, which may be in the range of 300 megahertz (MHz) to 300 gigahertz (GHz). Generally, the region from 300 MHz to 3 GHz is known as the ultra-high frequency (UHF) region or decimeter band because the wavelengths range from approximately one decimeter to one meter in length. The UHF waves may be blocked or redirected by buildings and environmental features, which may be referred to as clusters, but the waves may penetrate structures sufficiently for a macro cell to provide service to the UEs **115** located indoors. The transmission of UHF waves may be associated with smaller antennas and shorter ranges (e.g., less than 100 kilometers) compared to transmission using the smaller frequencies and longer waves of the high frequency (HF) or very high frequency (VHF) portion of the spectrum below 300 MHz.

The wireless communications system **100** may utilize both licensed and unlicensed RF spectrum bands. For example, the wireless communications system **100** may employ License Assisted Access (LAA), LTE-Unlicensed (LTE-U) radio access technology, or NR technology in an unlicensed band such as the 5 GHz industrial, scientific, and medical (ISM) band. While operating in unlicensed RF spectrum bands, devices such as the network entities **105** and the UEs **115** may employ carrier sensing for collision detection and avoidance. In some examples, operations in unlicensed bands may be based on a carrier aggregation configuration in conjunction with component carriers operating in a licensed band (e.g., LAA). Operations in unlicensed spectrum may include downlink transmissions, uplink transmissions, P2P transmissions, or D2D transmissions, among other examples.

A network entity **105** (e.g., a base station **140**, an RU **170**) or a UE **115** may be equipped with multiple antennas, which may be used to employ techniques such as transmit diversity, receive diversity, multiple-input multiple-output (MIMO) communications, or beamforming. The antennas of a network entity **105** or a UE **115** may be located within one or more antenna arrays or antenna panels, which may support MIMO operations or transmit or receive beamforming. For example, one or more base station antennas or antenna arrays may be co-located at an antenna assembly, such as an antenna tower. In some examples, antennas or antenna arrays associated with a network entity **105** may be located in diverse geographic locations. A network entity **105** may have an antenna array with a set of rows and columns of antenna ports that the network entity **105** may use to support beamforming of communications with a UE **115**. Likewise, a UE **115** may have one or more antenna arrays that may support various MIMO or beamforming operations. Additionally, or alternatively, an antenna panel may support RF beamforming for a signal transmitted via an antenna port.

The network entities **105** or the UEs **115** may use MIMO communications to exploit multipath signal propagation and increase the spectral efficiency by transmitting or receiving multiple signals via different spatial layers. Such techniques may be referred to as spatial multiplexing. The multiple signals may, for example, be transmitted by the transmitting device via different antennas or different combinations of antennas. Likewise, the multiple signals may be received by the receiving device via different antennas or different combinations of antennas. Each of the multiple signals may be referred to as a separate spatial stream and may carry information associated with the same data stream (e.g., the same codeword) or different data streams (e.g., different codewords). Different spatial layers may be associated with different antenna ports used for channel measurement and reporting. MIMO techniques include single-user MIMO (SU-MIMO), where multiple spatial layers are transmitted to the same receiving device, and multiple-user MIMO (MU-MIMO), where multiple spatial layers are transmitted to multiple devices.

Beamforming, which may also be referred to as spatial filtering, directional transmission, or directional reception, is a signal processing technique that may be used at a transmitting device or a receiving device (e.g., a network entity **105**, a UE **115**) to shape or steer an antenna beam (e.g., a transmit beam, a receive beam) along a spatial path between the transmitting device and the receiving device. Beamforming may be achieved by combining the signals communicated via antenna elements of an antenna array such that some signals propagating at particular orientations with respect to an antenna array experience constructive interference while others experience destructive interference. The adjustment of signals communicated via the antenna elements may include a transmitting device or a receiving device applying amplitude offsets, phase offsets, or both to signals carried via the antenna elements associated with the device. The adjustments associated with each of the antenna elements may be defined by a beamforming weight set associated with a particular orientation (e.g., with respect to the antenna array of the transmitting device or receiving device, or with respect to some other orientation).

A network entity **105** or a UE **115** may use beam sweeping techniques as part of beamforming operations. For example, a network entity **105** (e.g., a base station **140**, an RU **170**) may use multiple antennas or antenna arrays (e.g., antenna panels) to conduct beamforming operations for directional communications with a UE **115**. Some signals (e.g., synchronization signals, reference signals, beam selection signals, or other control signals) may be transmitted by a network entity **105** multiple times along different directions. For example, the network entity **105** may transmit a signal according to different beamforming weight sets associated with different directions of transmission. Transmissions along different beam directions may be used to identify (e.g., by a transmitting device, such as a network entity **105**, or by a receiving device, such as a UE **115**) a beam direction for later transmission or reception by the network entity **105**.

Some signals, such as data signals associated with a particular receiving device, may be transmitted by transmitting device (e.g., a transmitting network entity **105**, a transmitting UE **115**) along a single beam direction (e.g., a direction associated with the receiving device, such as a receiving network entity **105** or a receiving UE **115**). In some examples, the beam direction associated with transmissions along a single beam direction may be determined based on a signal that was transmitted along one or more beam directions. For example, a UE **115** may receive one or more of the signals transmitted by the network entity **105** along different directions and may report to the network entity **105** an indication of the signal that the UE **115** received with a highest signal quality or an otherwise acceptable signal quality.

In some examples, transmissions by a device (e.g., by a network entity **105** or a UE **115**) may be performed using multiple beam directions, and the device may use a combination of digital precoding or beamforming to generate a combined beam for transmission (e.g., from a network entity **105** to a UE **115**). The UE **115** may report feedback that indicates precoding weights for one or more beam directions, and the feedback may correspond to a configured set of beams across a system bandwidth or one or more subbands. The network entity **105** may transmit a reference signal (e.g., a cell-specific reference signal (CRS), a channel state information reference signal (CSI-RS)), which may be precoded or unprecoded. The UE **115** may provide feedback for beam selection, which may be a precoding matrix indicator (PMI) or codebook-based feedback (e.g., a multi-panel type codebook, a linear combination type codebook, a port selection type codebook). Although these techniques are described with reference to signals transmitted along one or more directions by a network entity **105** (e.g., a base station **140**, an RU **170**), a UE **115** may employ similar techniques for transmitting signals multiple times along different directions (e.g., for identifying a beam direction for subsequent transmission or reception by the UE **115**) or for transmitting a signal along a single direction (e.g., for transmitting data to a receiving device).

A receiving device (e.g., a UE **115**) may perform reception operations in accordance with multiple receive configurations (e.g., directional listening) when receiving various signals from a receiving device (e.g., a network entity **105**), such as synchronization signals, reference signals, beam selection signals, or other control signals. For example, a receiving device may perform reception in accordance with multiple receive directions by receiving via different antenna subarrays, by processing received signals according to different antenna subarrays, by receiving according to different receive beamforming weight sets (e.g., different directional listening weight sets) applied to signals received at multiple antenna elements of an antenna array, or by processing received signals according to different receive beamforming weight sets applied to signals received at multiple antenna elements of an antenna array, any of which may be referred to as "listening" according to different receive configurations or receive directions. In some examples, a receiving device may use a single receive configuration to receive along a single beam direction (e.g., when receiving a data signal). The single receive configuration may be aligned along a beam direction determined based on listening according to different receive configuration directions (e.g., a beam direction determined to have a highest signal strength, highest signal-to-noise ratio (SNR), or otherwise acceptable signal quality based on listening according to multiple beam directions).

A communications device (e.g., a UE **115**, a base station **140**, a TRP) operating within the wireless communications system **100**, may include one or more antennas for communicating with other communications device. As the number of antennas at the communications device increases, the number of possible antenna weight combinations to be used for generating directional beams may also increase, resulting in increased processing and power consumption at the communication device. As such, determining a suitable combination of beamforming weights based on static directional beams may be prohibitive for the communications device.

In some examples, however, the wireless communications system **100** may support one or more aspects of techniques for constructing a dynamic beam from multiple directional beams (e.g., using maximum ratio combining). For example, a first device (e.g., the UE **115** or the base station **140**) may monitor for a set of reference signals (e.g., SSBs, CSI-RSs, DMRS, or SRSs) from a second device (e.g., another UE **115** or another base station **140**) using a set of directional beams. The first device may perform measurements (e.g., RSRP measurements, SINR measurements, or both) on the received reference signals and select a subset of directional beams from the set of directional beams based on the performed measurements. Each directional beam may be associated with a set of beamforming weights (e.g., corresponding to a particular direction). The first device may communicate with the second device using a dynamic set of beamforming weights different from each set of beamforming weights associated with the subset of directional beams. For example, the first device may form the dynamic set of beamforming weights using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams. The present disclosure may therefore promote reduced processing and increased performance, among other benefits.

FIG. **2** illustrates an example of a wireless communications system **200** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The wireless communications system **200** may implement or be implemented by aspects of the wireless communications system **100**. For example, the wireless communications system **200** may include a network entity **205** and a UE **215**, which may be examples of the corresponding devices described with reference to FIG. **1**. The wireless communications system **200** may include features for improved communications between the UE **215** and the network entity **205**, among other benefits. In some examples of the wireless communications systems **200**, the actions performed by the UE **215** may be performed by other communication device, such as the network entity **205** Additionally or alternatively, the actions performed by the network entity **205** may be performed by other communication device, such as the UE **215**.

The UE **215** may communicate with the network entity **205** using beamforming techniques. For example, the UE **215** may communicate with the network entity **205** via one or more directional UE beams **220**. In some examples, the communications illustrated in FIG. **2** may include downlink transmissions to the UE **215**, where the directional UE beams **220** may be reception beams. Additionally or alternatively, the communications illustrated in FIG. **2** may include uplink transmissions (or sidelink transmissions to one or more other UEs (not shown)) from the UE **215**, where the directional UE beams **220** may be transmission beams. The UE **215** may include an antenna array **210** configured to transmit or receive beamformed transmissions (e.g., using the directional UE beams **220**). The UE **215** may include one or more additional antenna arrays **210** (not shown).

The antenna array **210** may include a set of antenna elements. For example, the UE **215** (e.g., and the network entity **205**) may use multiple antennas (e.g., antenna elements) for directional communications in the wireless communication system (e.g., in a mmW communications system). That is, a transmitting device (e.g., the network entity **205** or the UE **215**) may use multiple antenna elements to transmit signals (e.g., one or more reference signals) using one or more carrier frequencies. In some examples (e.g., if the transmitting device is the UE **215**), the one or more carrier frequencies may be mmW carrier frequencies (e.g., greater than about 24.25 GHz).

Beamforming (e.g., directional beamforming) via multiple antennas may be used to satisfy a performance metric (e.g., a link budget, a spectral efficiency (SPEFF), a block error rate (BLER), an SINR, an SNR, or an RSRP) associated with communications (e.g., transmitting or receiving signals) between communications device (e.g., the UE **215** and the network entity **205**) operating within the wireless communications system **200**. For example, the UE **215** may use multiple antennas (e.g., directional beamforming via multiple antenna) to improve the received signal strength of communications from the network entity **205**. In some examples, the UE **215** (e.g., and the network entity **205**) may use codebook-based directional beamforming. For example, beamforming operations, such as beam training, performed at the UE **215** may be based on a codebook in which codewords (e.g., associated with a combination of weights for respective antenna elements at the UE **215**) may be configured (e.g., predefined) at the UE **215** and the network entity **205**. That is, each codeword of the codebook may be used by the UE **215** to generate a beam in a particular direction.

In some examples, the number of beamforming weight combinations (e.g., associated with a respective codeword) may be rigid (e.g., fixed). For example, the codebook may be stored in memory (e.g., radio frequency identification (RFID) memory) at the UE **215** (e.g., and the network entity **205**). However, due to a rigid memory storage capacity (e.g., and complexities associated with determining possible beamforming weight combination), the number of codewords in in the codebook may be static (e.g., fixed). As such, beamforming operations with such a codebook may be referred to as static codebook beamforming (e.g., a static codebook approach to beamforming). In some examples of static codebook beamforming, scenarios may occur in which a suitable beamforming direction (e.g., or suitable combinations of beamforming weights) may not be included in the codebook. As a result, scenarios may occur in which the UE **215** may determine to use dynamic (e.g., adaptive) beamforming weights beyond what may be included in the codebook.

However, constructing dynamic beamforming weights (e.g., a dynamic set of beamforming weights) at the UE **215** may increase the number of measurements to be performed by the UE **215** and, accordingly, increase the processing and power consumption at the UE **215**. For example, the UE **215** may use a maximum ratio combining scheme (e.g., direct maximum ratio combining) to construct the dynamic set of beamforming weights. However, the quality of the dynamic set of beamforming weights determined by the UE **215** may be influenced by (e.g., may increase with) the number of measurements performed at the UE **215**, for example due to latency (e.g., associated with the channel becoming outdated or changing) and noise associated with performing measurements at a relatively low SNR.

In some examples, to improve coverage, diversity, and cost effectiveness, the number of antennas at a communication device (e.g., the UE **215**) may be increased. For example, the UE **215** (e.g., and other customer premise equipments (CPEs) operating within the wireless communications system **200**, not shown) may use multiple antenna arrays, which may each include multiple modules (e.g., panels), to improve coverage (e.g., signal coverage area), diversity (e.g., signal diversity), and cost effectiveness. However, the number of measurements to be performed by the UE **215** may be based on (e.g., may scale with) the number of antennas at the UE **215** and may become prohibitive for the UE **215** as the number of antennas at the UE **215** exceeds a threshold. As a concrete example, the number of measurements to be performed by a CPE with 64 antennas may result in a latency at the CPE that may exceed a coherence time threshold (e.g., up to hundreds of ms). Moreover, measurements performed on signals with a reduced SNR may increase the likelihood of erroneous estimates. For example, a pre-beamforming SNR (e.g., −10 dB), may result in unreliable phase and power estimates (e.g., measurements).

Therefore, to decrease the processing and power consumption at the UE **215**, while improving the performance, the UE **215** may use static (e.g., directional) beams as the basis for constructing the dynamic beamforming weights. That is, the UE **215** may determine a suitable beamforming weight combination (a dynamic set beamforming weights) by combining beamforming weights of directional beams (e.g., two or more directional UE beams **220**). For example, a dynamic beam (e.g., generated using a dynamic set of beamforming weights) which increases the received power at the UE **215** may be constructed with a linear combination of multi-path components (e.g., in the environment of the UE **215**). For example, signals transmitted from the network entity **205** may experience multi-path propagation, such that the transmitted signals (e.g., reference signals) may reach the UE **215** by multiple (e.g., more than two) paths.

For example, signals transmitted from the network entity **205** may reach the UE **215** via one or more paths **235** (e.g., a path **235**-*a*, a path **235**-*b*, and a path **235**-*c*). Multi-path propagation may result from atmospheric ducting, refraction, or reflection off of objects in the surrounding area. For example, signals transmitted from the network entity **205** may interact with nearby reflectors (e.g., buildings, humans, vehicles, and the like) prior to arriving at the UE **215**. In other words, signals transmitted by the network entity **205** may each excite a multi-path component, which may include a respective path between the network entity **205** and the UE **215** (e.g., the path **235**-*a*, the path **235**-*b*, and the path **235**-*c*). In some examples, reflectors may be referred to as objects. For example, the network entity **205** may transmit signals to the UE **215** and at least a portion of a signal may reflect off of one or more objects **230** (e.g., an object **230**-*a*, an object **230**-*b*, and/or an object **230**-*c*) towards the UE **215**. In some examples, multi-path propagation may result in interference and phase shifting of the transmitted signals (e.g., multi-path interference or multi-path distortion), which may affect the signals prior to detection at the UE **215**. As such, the UE **215** may exploit multi-path propagation to determine a dynamic beam (e.g., a dynamic set of beamforming weights) for communications with the network entity **205**.

In some examples, the UE **215** may treat (e.g., view) the directional UE beams **220** as virtual antennas and use antenna selection and antenna combining to determine the dynamic set of beamforming weights. For example, the UE **215** may estimate the angle of arrival (e.g., and power) of multi-path components by steering (e.g., generating) directional beams (e.g., relatively narrow directional beams) toward different directions. For example, the UE **215** may use a beam sweeping procedure (e.g., as part of an initial access procedure to gain access to the channel) and determine an angle of arrival for multi-path components. In some examples, the UE **215** may use a parameter extraction algorithm to extract (e.g., determine) the angle of arrival of multi-path components in the channel to construct the dynamic beam. For example, the UE **215** may use the parameter extraction algorithm to determine the angle of arrival of the multi-path components and then use an optimization algorithm to construct the dynamic beam.

The UE **215** may select the directional beams (e.g., virtual antennas) based on the angle of arrival of the multi-path components and the received power at each virtual antenna (e.g., used during the beam sweeping procedure). For example, the UE **215** may select the directional beams with a relatively high signal quality, or an otherwise acceptable signal quality, compared to other directional beams used during the beam sweeping procedure to construct the dynamic beam (e.g., to form the dynamic set of beamforming weights). In some examples, the UE **215** may select a directional beam based on whether the directional beam satisfies a performance metric, such as a link budget, an SPEFF, a BLER, an SINR, an SNR, or an RSRP. In the example of FIG. **2**, the directional beam **220**-*a*, the directional beam **220**-*b*, and the directional beam **220**-*d* may have a relatively high signal quality compared to the directional beam **220**-*c* and the directional beam **220**-*e*. As such, the UE may select the directional beam **220**-*a*, the directional beam **220**-*b*, and the directional beam **220**-*d* to form a dynamic UE beam **225**. The selected directional beams may be combined using a technique based on maximum ratio combining (e.g., using the maximum ratio combining concept), equal gain combining, or optimum combining (e.g., optimum combining strategies).

For example, the UE **215** may construct the dynamic UE beam **225** (e.g., the dynamic set of beamforming weights) using hybrid-beam selection and maximum ratio combining. In some examples of hybrid-beam selection and maximum ratio combining, the UE **215** may select a number (K) of beams with a relatively high signal quality (e.g., a relatively high RSRP value or a relatively high SINR value) or an otherwise acceptable signal quality compared to other directional beams. The selected beams (e.g., $b_{(1)} \ldots b_{(K)}$) may be represented by Equation 1, as follows:

$$B=[b_{(1)} \ldots b_{(K)}] \tag{1}$$

where $b_{(1)}$, may represent a beam design parameter. The UE **215** may construct a covariance matrix (R) between the observed signals received via the (K) selected beams. That is, the UE **215** may calculate the correlation between the (K) virtual antennas to construct a covariance matrix (R) of size K×K. The UE **215** may determine (e.g., find, compute, calculate) a dominant eigenvector (u) of the covariance matrix. The dominant eigenvector (u) may be a matrix of size K×1. The UE **215** may form the dynamic beam (g) according to Equation 2. That is, the UE **215** may combine the directional beams using Equation 2:

$$g = \frac{1}{|Bu|}Bu. \quad (2)$$

In some examples, hybrid-beam selection and maximum ratio combining may provide a reduction in the number of measurements to be performed by the UE **215** for determining a suitable combination of beamforming weights. For example, the number of measurements (e.g., and the duration of time) used to construct the dynamic set of beamforming weights may be reduced for hybrid-beam selection and maximum ratio combining compared to other techniques, such as static (e.g., directional) beam techniques or direct maximum ratio combining, for determining a suitable combination of beamforming weights. Additionally or alternatively, the fiftieth percentile of a rank-1 spectral efficiency for hybrid-beam selection and maximum ratio combining may be comparable to the fiftieth percentile of a rank-1 spectral efficiency for static beam techniques and direct maximum ratio combining, while providing a reduction in the number of measurements (e.g., and duration of time) used to construct the dynamic set of beamforming weights. That is, hybrid-beam selection and maximum ratio combining may provide a flexible technique for approaching a modeled set of beamforming weights. For example, hybrid-beam selection and maximum ratio combining may provide a reduction in the number of measurements used to construct the dynamic set of beamforming weights compared to other beamforming techniques, such as sweeping of static beams and direct maximum ratio combining. For instance, for a device with 32 antennas, hybrid-beam selection and maximum ratio combining may reduce the number of measurements by about half (e.g., by about 50 percent or a percentage greater than about 50). In some examples, the amount by which the measurements are reduced may depend on the number of selected beams (K), the method used to construct the dynamic beam weights, or both.

Additionally or alternatively, using hybrid-beam selection and maximum ratio combining to construct the dynamic set of beamforming weights may improve (e.g., boost) the SNR of measured signals (e.g., measured reference signals). In some examples (e.g., for a transceiver with 64 antenna elements), the ratio of post-beamforming SNR to pre-beamforming SNR for hybrid-beam selection and maximum ratio combining may be comparable to the ratio of post-beamforming SNR to pre-beamforming SNR for static beam techniques. For example, a resistance to noise at relatively low SNR values may be increased compared other beamforming techniques. For example, hybrid-beam selection and maximum ratio combining may provide a gain (e.g., of 13 dB with K=2) over direct maximum ratio combining. In some examples, the performance for hybrid-beam selection and maximum ratio combining may depend on the number (K) of combined beams. The number of combined beams may be greater than one (e.g., may range from 2 to a maximum number of static beam weights, such as 91). In some examples, as the number (K) of combined beams exceeds a threshold, relatively weak directional beams (e.g., relatively weak virtual antennas) of the number (K) of combined beams that exceed the threshold, may impact the performance of the UE **215**. For example, the gain provided by hybrid-beam selection and maximum ratio combining (e.g., over direct maximum ratio combining) may be reduced (e.g., to 2.9 dB) for an increased number of combined beams (e.g., for K=91).

In some examples of hybrid-beam selection and maximum ratio combining, a beam pattern (e.g., a dynamic beam generated using the dynamic set of directional beamform weights) used by the UE **215** to receive signals may depend on the angle of arrival of the received signals (e.g., the multi-path components). For example, for a given multi-path component (e.g., or a set of multi-path components) the UE **215** may use a beam pattern that may increase the received power (e.g., the measured RSRP or the measured SINR) at the UE **215**. That is, the receive power measured at the UE **215** may depend on the beam pattern used at the UE **215**. Additionally or alternatively, the received power measured at the UE **215** may depend on whether the UE **215** is using static beams or a dynamic beam. Thus, hybrid-beam selection and maximum ratio combining may be used to increase the received signal power at the UE **215**, thereby enhancing communications efficiency and throughput.

FIG. **3** illustrates an example of a process flow **300** in a system that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The process flow **300** may implement or be implemented by one or more aspects of the wireless communications system **100** and the wireless communications system **200**. For example, the process flow **300** may include one or more devices **305** (e.g., a device **305**-*a* and a device **305**-*b*), which may be examples of a network entity or a UE described with reference to FIGS. **1** and **2**. The process flow **300** may be implemented by the device **305**-*a* or the device **305**-*b*, or both. In the following description of the process flow **300**, operations between the device **305**-*a* and the device **305**-*b* may occur in a different order or at different times than as shown. Some operations may also be omitted from the process flow **300**, and other operations may be added to the process flow **300**.

At **310**, the device **305**-*a* may monitor for a set of reference signals (e.g., a set of SSBs, a set of CSI-RSs, a set of DMRSs, or a set of SRSs) from the device using a set of directional beams. Each directional beam of the set may be an example of a directional beam described with reference to FIG. **2**. For example, the device **305**-*a* may generate the set of directional beams based on a respective set of beamforming weights. The respective set of beamforming weights may include a weighting applied to an antenna element of a subset of antenna elements at the device **305**-*a*. As an example, at **315**, the device **305**-*b* may transmit reference signals (e.g., the set of reference signals) to the device **305**-*a*, and the device **305**-*a* may receive the set of reference signals using the set of directional beams.

At **320**, the device **305**-*a* may select a subset of directional beams from the set of directional beams. In some example, the device **305**-*a* may select the subset of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams. The subset of directional beams may be selected based on the measurements associated with a particular beam and one or more performance metrics (e.g., an SPEFF, a BLER, an SINR, and SNR, a RSRP). Additionally or alternatively, the subset of directional beams may be selected based on the measurements associated with a particular beam satisfying a threshold.

In some examples, at **325**, the device **305**-*a* may determine a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the device **305**-*a*. For example, the device **305**-*a* may determine the covariance matrix based on the one or more measurements. The covariance matrix may be an example of a covariance matrix described with reference to FIG. **2**. In some examples, at **330**, the device **305**-*a* may determine one or more eigenvectors associated with the covariance matrix. The one or more eigenvectors may satisfy a threshold. In some examples, the eigenvectors may be examples of dominant eigenvectors described with reference to FIG. **2**.

At **335**, the device **305**-*a* may communicate (e.g., with the device **305**-*b*) using a dynamic set of beamforming weights (e.g., one or more dynamic beams) that may be formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams. The dynamic set of beamforming weights may be an example of a dynamic set of beamforming weights described with reference to FIG. **2**. For example, the dynamic set of beamforming weights may be different from each set of beamforming weights associated with the subset of directional beams. In some examples, the combination may be formed using hybrid-beam selection and maximum ratio combining. For example, the combination may be based on the one or more eigenvectors (e.g., one or more dominant eigenvectors). As a result, the device **305**-*a* may reduce processing and power consumption while improving performance. For example, the techniques as described herein may provide increased flexibility and gains compared to static beamforming techniques (e.g., or direct maximum ratio combining).

FIG. **4** shows a block diagram **400** of a device **405** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The device **405** may be an example of aspects of a device (e.g., a network entity or a UE) as described herein. The device **405** may include a receiver **410**, a transmitter **415**, and a communications manager **420**. The device **405** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **410** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to methods for dynamic beamforming weight construction based on directional measurements). Information may be passed on to other components of the device **405**. The receiver **410** may utilize a single antenna or a set of multiple antennas.

The transmitter **415** may provide a means for transmitting signals generated by other components of the device **405**. For example, the transmitter **415** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to methods for dynamic beamforming weight construction based on directional measurements). In some examples, the transmitter **415** may be co-located with a receiver **410** in a transceiver module. The transmitter **415** may utilize a single antenna or a set of multiple antennas.

The communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations thereof or various components thereof may be examples of means for performing various aspects of methods for dynamic beamforming weight construction based on directional measurements as described herein. For example, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may support a method for performing one or more of the functions described herein.

In some examples, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some examples, a processor and memory coupled with the processor may be configured to perform one or more of the functions described herein (e.g., by executing, by the processor, instructions stored in the memory).

Additionally or alternatively, in some examples, the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be implemented in code (e.g., as communications management software or firmware) executed by a processor. If implemented in code executed by a processor, the functions of the communications manager **420**, the receiver **410**, the transmitter **415**, or various combinations or components thereof may be performed by a general-purpose processor, a DSP, a central processing unit (CPU), an ASIC, an FPGA, or any combination of these or other programmable logic devices (e.g., configured as or otherwise supporting a means for performing the functions described in the present disclosure).

In some examples, the communications manager **420** may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **410**, the transmitter **415**, or both. For example, the communications manager **420** may receive information from the receiver **410**, send information to the transmitter **415**, or be integrated in combination with the receiver **410**, the transmitter **415**, or both to receive information, transmit information, or perform various other operations as described herein.

The communications manager **420** may support wireless communication at a first device (e.g., device **405**) in accordance with examples as disclosed herein. For example, the communications manager **420** may be configured as or otherwise support a means for monitoring for a set of reference signals from a second device (e.g., another device **405**) using a set of directional beams. The communications manager **420** may be configured as or otherwise support a means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The communications manager **420** may be configured as or otherwise support a means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams.

By including or configuring the communications manager **420** in accordance with examples as described herein, the device **405** (e.g., a processor controlling or otherwise coupled with the receiver **410**, the transmitter **415**, the communications manager **420**, or a combination thereof) may support techniques for reduced processing, reduced power consumption, and more efficient utilization of communication resources.

FIG. **5** shows a block diagram **500** of a device **505** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The device **505** may be an example of aspects of a device **405**, a UE **115**, or a network entity **105** as described herein. The device **505** may include a receiver **510**, a transmitter **515**, and a communications manager **520**. The device **505** may also include a processor. Each of these components may be in communication with one another (e.g., via one or more buses).

The receiver **510** may provide a means for receiving information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to methods for dynamic beamforming weight construction based on directional measurements). Information may be passed on to other components of the device **505**. The receiver **510** may utilize a single antenna or a set of multiple antennas.

The transmitter **515** may provide a means for transmitting signals generated by other components of the device **505**. For example, the transmitter **515** may transmit information such as packets, user data, control information, or any combination thereof associated with various information channels (e.g., control channels, data channels, information channels related to methods for dynamic beamforming weight construction based on directional measurements). In some examples, the transmitter **515** may be co-located with a receiver **510** in a transceiver module. The transmitter **515** may utilize a single antenna or a set of multiple antennas.

The device **505**, or various components thereof, may be an example of means for performing various aspects of methods for dynamic beamforming weight construction based on directional measurements as described herein. For example, the communications manager **520** may include a reference signal monitoring component **525**, a directional beam component **530**, a dynamic beamforming component **535**, or any combination thereof. The communications manager **520** may be an example of aspects of a communications manager **420** as described herein. In some examples, the communications manager **520**, or various components thereof, may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the receiver **510**, the transmitter **515**, or both. For example, the communications manager **520** may receive information from the receiver **510**, send information to the transmitter **515**, or be integrated in combination with the receiver **510**, the transmitter **515**, or both to receive information, transmit information, or perform various other operations as described herein.

The communications manager **520** may support wireless communication at a first device (e.g., the device **505**) in accordance with examples as disclosed herein. The reference signal monitoring component **525** may be configured as or otherwise support a means for monitoring for a set of reference signals from a second device (e.g., another device **505**) using a set of directional beams. The directional beam component **530** may be configured as or otherwise support a means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The dynamic beamforming component **535** may be configured as or otherwise support a means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams.

FIG. **6** shows a block diagram **600** of a communications manager **620** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The communications manager **620** may be an example of aspects of a communications manager **420**, a communications manager **520**, or both, as described herein. The communications manager **620**, or various components thereof, may be an example of means for performing various aspects of methods for dynamic beamforming weight construction based on directional measurements as described herein. For example, the communications manager **620** may include a reference signal monitoring component **625**, a directional beam component **630**, a dynamic beamforming component **635**, a covariance matrix component **640**, an eigenvector component **645**, a performance metric component **650**, a multi-path component **655**, or any combination thereof. Each of these components may communicate, directly or indirectly, with one another (e.g., via one or more buses).

The communications manager **620** may support wireless communication at a first device (e.g., a UE or a network entity) in accordance with examples as disclosed herein. The reference signal monitoring component **625** may be configured as or otherwise support a means for monitoring for a set of reference signals from a second device (e.g., another UE or another network entity) using a set of directional beams. The directional beam component **630** may be configured as or otherwise support a means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The dynamic beamforming component **635** may be configured as or otherwise support a means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams.

In some examples, the covariance matrix component **640** may be configured as or otherwise support a means for determining, based on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of directional beams. In some examples, the eigenvector component **645** may be configured as or otherwise support a means for determining one or more eigenvectors associated with the covariance matrix, where the one or more eigenvectors satisfy a threshold, and where the combination is based on the one or more eigenvectors.

In some examples, the directional beam component **630** may be configured as or otherwise support a means for generating each directional beam of the set of directional beams based on a respective set of beamforming weights, where each respective set of beamforming weights corresponds to a direction of a set of multiple directions, and where receiving the set of reference signals using the set of directional beams is based on generating each directional beam.

In some examples, each beamforming weight of the respective set of beamforming weights includes a weighting applied to an antenna element of a subset of antenna elements at the first device. In some examples, each reference signal of the set of reference signals corresponds to a multi-path component of a set of multi-path components, each multi-path component including a respective signal path between the first device and the second device.

In some examples, the multi-path component **655** may be configured as or otherwise support a means for determining an angle of arrival associated with each multi-path component of the set of multi-path components, where selecting the subset of directional beams is based on the angle of arrival associated with each multi-path component of the set of multi-path components. In some examples, the performance metric component **650** may be configured as or otherwise support a means for determining a performance metric associated with communications between the first device and the second device, where a number of directional beams including the subset of directional beams is based on the performance metric.

In some examples, the performance metric includes a link budget, an effective spectral efficiency, a block error rate, a signal-to-interference-plus-noise ratio, a signal-to-noise ratio, or a reference signal received power ratio. In some examples, to support selecting the subset of directional beams, the directional beam component **630** may be configured as or otherwise support a means for determining, based on the one or more measurements, one or more directional beams of the set of directional beams that satisfy a threshold, where the subset of directional beams includes the one or more directional beams that satisfy the threshold.

In some examples, the first device includes a network entity and each reference signal of the set of reference signals includes a sounding reference signal. In some examples, the first device includes a user equipment and each reference signal of the set of reference signals includes a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

In some examples, the one or more measurements include one or more reference signal received power measurements or one or more signal-to-interference-plus-noise ratio measurements. In some examples, the combination is based on maximum ratio combining, or equal gain combining, or one or more optimum combining strategies, or any combination thereof. In some examples, the first device includes a UE and each reference signal of the set of reference signals is transmitted using one or more mmW carrier frequencies. In some examples, the one or more mmW carrier frequencies are greater than about 24.25 GHz. In some examples, the first device includes a network entity and each reference signal of the set of reference signals is transmitted using one or more carrier frequencies.

FIG. **7** shows a diagram of a system **700** including a device **705** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The device **705** may be an example of or include the components of a device **405**, a device **505**, or a UE **115** as described herein. The device **705** may communicate wirelessly with one or more network entities **105**, UEs **115**, or any combination thereof. The device **705** may include components for bi-directional voice and data communications including components for transmitting and receiving communications, such as a communications manager **720**, an input/output (I/O) controller **710**, a transceiver **715**, an antenna **725**, a memory **730**, code **735**, and a processor **740**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **745**).

The I/O controller **710** may manage input and output signals for the device **705**. The I/O controller **710** may also manage peripherals not integrated into the device **705**. In some cases, the I/O controller **710** may represent a physical connection or port to an external peripheral. In some cases, the I/O controller **710** may utilize an operating system such as iOS®, ANDROID®, MS-DOS®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. Additionally or alternatively, the I/O controller **710** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **710** may be implemented as part of a processor, such as the processor **740**. In some cases, a user may interact with the device **705** via the I/O controller **710** or via hardware components controlled by the I/O controller **710**.

In some cases, the device **705** may include a single antenna **725**. However, in some other cases, the device **705** may have more than one antenna **725**, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver **715** may communicate bi-directionally, via the one or more antennas **725**, wired, or wireless links as described herein. For example, the transceiver **715** may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver. The transceiver **715** may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas **725** for transmission, and to demodulate packets received from the one or more antennas **725**. The transceiver **715**, or the transceiver **715** and one or more antennas **725**, may be an example of a transmitter **415**, a transmitter **515**, a receiver **410**, a receiver **510**, or any combination thereof or component thereof, as described herein.

The memory **730** may include random access memory (RAM) and read-only memory (ROM). The memory **730** may store computer-readable, computer-executable code **735** including instructions that, when executed by the processor **740**, cause the device **705** to perform various functions described herein. The code **735** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **735** may not be directly executable by the processor **740** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the memory **730** may contain, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

The processor **740** may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **740** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **740**. The processor **740** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **730**) to cause the device **705** to perform various functions (e.g., functions or tasks supporting methods for dynamic beamforming weight construction based on directional measurements). For example, the device **705** or a component of the device **705** may include a processor **740** and memory **730** coupled with or to the processor **740**, the processor **740** and memory **730** configured to perform various functions described herein.

The communications manager **720** may support wireless communication at a first device (e.g., the device **705**) in accordance with examples as disclosed herein. For example, the communications manager **720** may be configured as or otherwise support a means for monitoring for a set of reference signals from a second device (e.g., another device **705**) using a set of directional beams. The communications manager **720** may be configured as or otherwise support a means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The communications manager **720** may be configured as or otherwise support a means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams.

By including or configuring the communications manager **720** in accordance with examples as described herein, the device **705** may support techniques for reduced latency, improved user experience related to reduced processing, reduced power consumption, more efficient utilization of communication resources, and longer battery life.

In some examples, the communications manager **720** may be configured to perform various operations (e.g., receiving, monitoring, transmitting) using or otherwise in cooperation with the transceiver **715**, the one or more antennas **725**, or any combination thereof. Although the communications manager **720** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **720** may be supported by or performed by the processor **740**, the memory **730**, the code **735**, or any combination thereof. For example, the code **735** may include instructions executable by the processor **740** to cause the device **705** to perform various aspects of methods for dynamic beamforming weight construction based on directional measurements as described herein, or the processor **740** and the memory **730** may be otherwise configured to perform or support such operations.

FIG. **8** shows a diagram of a system **800** including a device **805** that supports methods for dynamic beam construction based on directional measurements in accordance with one or more aspects of the present disclosure. The device **805** may be an example of or include the components of a device **405**, a device **505**, or a network entity **105** as described herein. The device **805** may communicate with one or more network entities **105**, one or more UEs **115**, or any combination thereof, which may include communications over one or more wired interfaces, over one or more wireless interfaces, or any combination thereof. The device **805** may include components that support outputting and obtaining communications, such as a communications manager **820**, a transceiver **810**, an antenna **815**, a memory **825**, code **830**, and a processor **835**. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more buses (e.g., a bus **840**).

The transceiver **810** may support bi-directional communications via wired links, wireless links, or both as described herein. In some examples, the transceiver **810** may include a wired transceiver and may communicate bi-directionally with another wired transceiver. Additionally, or alternatively, in some examples, the transceiver **810** may include a wireless transceiver and may communicate bi-directionally with another wireless transceiver. In some examples, the device **805** may include one or more antennas **815**, which may be capable of transmitting or receiving wireless transmissions (e.g., concurrently). The transceiver **810** may also include a modem to modulate signals, to provide the modulated signals for transmission (e.g., by one or more antennas **815**, by a wired transmitter), to receive modulated signals (e.g., from one or more antennas **815**, from a wired receiver), and to demodulate signals. The transceiver **810**, or the transceiver **810** and one or more antennas **815** or wired interfaces, where applicable, may be an example of a transmitter **415**, a transmitter **515**, a receiver **410**, a receiver **510**, or any combination thereof or component thereof, as described herein. In some examples, the transceiver may be operable to support communications via one or more communications links (e.g., a communication link **125**, a backhaul communication link **120**, a midhaul communication link **162**, a fronthaul communication link **168**).

The memory **825** may include RAM and ROM. The memory **825** may store computer-readable, computer-executable code **830** including instructions that, when executed by the processor **835**, cause the device **805** to perform various functions described herein. The code **830** may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some cases, the code **830** may not be directly executable by the processor **835** but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In some cases, the memory **825** may contain, among other things, a BIOS which may control basic hardware or software operation such as the interaction with peripheral components or devices.

The processor **835** may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA, a microcontroller, a programmable logic device, discrete gate or transistor logic, a discrete hardware component, or any combination thereof). In some cases, the processor **835** may be configured to operate a memory array using a memory controller. In some other cases, a memory controller may be integrated into the processor **835**. The processor **835** may be configured to execute computer-readable instructions stored in a memory (e.g., the memory **825**) to cause the device **805** to perform various functions (e.g., functions or tasks supporting methods for dynamic beam construction based on directional measurements). For example, the device **805** or a component of the device **805** may include a processor **835** and memory **825** coupled with the processor **835**, the processor **835** and memory **825** configured to perform various functions described herein. The processor **835** may be an example of a cloud-computing platform (e.g., one or more physical nodes and supporting software such as operating systems, virtual machines, or container instances) that may host the functions (e.g., by executing code **830**) to perform the functions of the device **805**.

In some examples, a bus **840** may support communications of (e.g., within) a protocol layer of a protocol stack. In some examples, a bus **840** may support communications associated with a logical channel of a protocol stack (e.g., between protocol layers of a protocol stack), which may include communications performed within a component of the device **805**, or between different components of the device **805** that may be co-located or located in different locations (e.g., where the device **805** may refer to a system in which one or more of the communications manager **820**, the transceiver **810**, the memory **825**, the code **830**, and the processor **835** may be located in one of the different components or divided between different components).

In some examples, the communications manager **820** may manage aspects of communications with a core network **130** (e.g., via one or more wired or wireless backhaul links). For example, the communications manager **820** may manage the transfer of data communications for client devices, such as one or more UEs **115**. In some examples, the communications manager **820** may manage communications with other network entities **105**, and may include a controller or scheduler for controlling communications with UEs **115** in cooperation with other network entities **105**. In some examples, the communications manager **820** may support an X2 interface within an LTE/LTE-A wireless communications network technology to provide communication between network entities **105**.

The communications manager **820** may support wireless communication at a first device in accordance with examples as disclosed herein. For example, the communications manager **820** may be configured as or otherwise support a means for monitoring for a set of reference signals from a second device using a set of directional beams. The communications manager **820** may be configured as or otherwise support a means for selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The communications manager **820** may be configured as or otherwise support a means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams.

By including or configuring the communications manager **820** in accordance with examples as described herein, the device **805** may support techniques for reduced latency, improved user experience related to reduced processing, reduced power consumption, more efficient utilization of communication resources, and longer battery life. In some examples, through the selection of a dynamic directional beam, the communications manager **820** may provide for improved throughput achieved through forming an optimal directional beam for communications with one or more other communication devices.

In some examples, the communications manager **820** may be configured to perform various operations (e.g., receiving, obtaining, monitoring, outputting, transmitting) using or otherwise in cooperation with the transceiver **810**, the one or more antennas **815** (e.g., where applicable), or any combination thereof. Although the communications manager **820** is illustrated as a separate component, in some examples, one or more functions described with reference to the communications manager **820** may be supported by or performed by the processor **835**, the memory **825**, the code **830**, the transceiver **810**, or any combination thereof. For example, the code **830** may include instructions executable by the processor **835** to cause the device **805** to perform various aspects of methods for dynamic beam construction based on directional measurements as described herein, or the processor **835** and the memory **825** may be otherwise configured to perform or support such operations.

FIG. **9** shows a flowchart illustrating a method **900** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The operations of the method **900** may be implemented by a UE or a network entity, or components of a UE or a network entity, as described herein. For example, the operations of the method **900** may be performed by a UE **115** or a network entity **105** as described with reference to FIGS. **1** through **7**. In some examples, a UE or a network entity may execute a set of instructions to control the functional elements of the UE or the network entity, respectively, to perform the described functions. Additionally or alternatively, the UE or the network entity may perform aspects of the described functions using special-purpose hardware.

At **905**, the method may include monitoring for a set of reference signals from a second device (e.g., another UE or another network entity) using a set of directional beams. The operations of **905** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **905** may be performed by a reference signal monitoring component **625** as described with reference to FIG. **6**.

At **910**, the method may include selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The operations of **910** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **910** may be performed by a directional beam component **630** as described with reference to FIG. **6**.

At **915**, the method may include communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams. The operations of **915** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **915** may be performed by a dynamic beamforming component **635** as described with reference to FIG. **6**.

FIG. **10** shows a flowchart illustrating a method **1000** that supports methods for dynamic beamforming weight construction based on directional measurements in accordance with aspects of the present disclosure. The operations of the method **1000** may be implemented by a UE or a network entity, or the components of a UE or a network entity, as described herein. For example, the operations of the method **1000** may be performed by a UE **115** or a network entity **105** as described with reference to FIGS. **1** through **7**. In some examples, a UE or a network entity may execute a set of instructions to control the functional elements of the UE or the network entity, respectively, to perform the described functions. Additionally or alternatively, the UE or the network entity may perform aspects of the described functions using special-purpose hardware.

At **1005**, the method may include monitoring for a set of reference signals from a second device (e.g., another UE or another network entity) using a set of directional beams. The operations of **1005** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1005** may be performed by a reference signal monitoring component **625** as described with reference to FIG. **6**.

At **1010**, the method may include selecting, by the first device, a subset of directional beams from the set of directional beams based on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights. The operations of **1010** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1010** may be performed by a directional beam component **630** as described with reference to FIG. **6**.

At **1015**, the method may include determining, based on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of directional beams. The operations of **1015** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1015** may be performed by a covariance matrix component **640** as described with reference to FIG. **6**.

At **1020**, the method may include determining one or more eigenvectors associated with the covariance matrix, where the one or more eigenvectors satisfy a threshold. The operations of **1020** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1020** may be performed by an eigenvector component **645** as described with reference to FIG. **6**.

At **1025**, the method may include communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, where the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of directional beams, and where the combination is based on the one or more eigenvectors. The operations of **1025** may be performed in accordance with examples as disclosed herein. In some examples, aspects of the operations of **1025** may be performed by a dynamic beamforming component **635** as described with reference to FIG. **6**.

The following provides an overview of aspects of the present disclosure:

Aspect 1: A method for wireless communication at a first device, comprising: monitoring for a set of reference signals from a second device using a set of directional beams; selecting, by the first device, a subset of directional beams from the set of directional beams based at least in part on performing one or more measurements of the set of reference signals received on the set of directional beams, each directional beam of the subset of directional beams being associated with a set of beamforming weights; and communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of directional beams, wherein the dynamic set of beamforming weights is different from each set of beam weights associated with the subset of directional beams.

Aspect 2: The method of aspect 1, further comprising: determining, based at least in part on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of directional beams; and determining one or more eigenvectors associated with the covariance matrix, wherein the one or more eigenvectors satisfy a threshold, and wherein the combination is based at least in part on the one or more eigenvectors.

Aspect 3: The method of any of aspects 1 through 2, further comprising: generating each directional beam of the set of directional beams based at least in part on a respective set of beamforming weights, wherein each respective set of beamforming weights corresponds to a direction of a plurality of directions, and wherein receiving the set of reference signals using the set of directional beams is based at least in part on generating each directional beam.

Aspect 4: The method of aspect 3, wherein each beamforming weight of the respective set of beamforming weights comprises a weighting applied to an antenna element of a subset of antenna elements at the first device.

Aspect 5: The method of any of aspects 1 through 4, wherein each reference signal of the set of reference signals excites a multi-path component of a set of multi-path components, each multi-path component comprising a respective signal path between the first device and the second device.

Aspect 6: The method of aspect 5, further comprising: determining an angle of arrival associated with each multi-path component of the set of multi-path components, wherein selecting the subset of directional beams is based at least in part on the angle of arrival associated with each multi-path component of the set of multi-path components.

Aspect 7: The method of any of aspects 1 through 6, further comprising: determining a performance metric associated with communications between the first device and the second device, wherein a number of directional beams comprising the subset of directional beams is based at least in part on the performance metric.

Aspect 8: The method of aspect 7, wherein the performance metric comprises a link budget, an effective spectral efficiency, a block error rate, a signal-to-interference-plus-noise ratio, a signal-to-noise ratio, or a reference signal received power ratio.

Aspect 9: The method of any of aspects 1 through 8, wherein selecting the subset of directional beams comprises: determining, based at least in part on the one or more measurements, one or more directional beams of the set of directional beams that satisfy a threshold, wherein the subset of directional beams comprises the one or more directional beams that satisfy the threshold.

Aspect 10: The method of any of aspects 1 through 9, wherein the first device comprises a network entity and each reference signal of the set of reference signals comprises a sounding reference signal.

Aspect 11: The method of any of aspects 1 through 9, wherein the first device comprises a user equipment and each reference signal of the set of reference signals comprises a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

Aspect 12: The method of any of aspects 1 through 11, wherein the one or more measurements comprise one or more reference signal received power measurements or one or more signal-to-interference-plus-noise ratio measurements.

Aspect 13: The method of any of aspects 1 through 12, wherein the combination is based at least in part on maximum ratio combining, or equal gain combining, or one or more optimum combining strategies, or any combination thereof.

Aspect 14: The method of any of aspects 1 through 13, wherein the first device comprises a UE and each reference signal of the set of reference signals is transmitted using one or more millimeter wave carrier frequencies.

Aspect 15: The method of aspect 14, wherein the one or more millimeter wave carrier frequencies are greater than about 24.25 gigahertz.

Aspect 16: The method of any of aspects 1 through 13, wherein the first device comprises a network entity and each reference signal of the set of reference signals is transmitted using one or more carrier frequencies.

Aspect 17: An apparatus for wireless communication at a first device, comprising a processor; memory coupled with the processor; and instructions stored in the memory and executable by the processor to cause the apparatus to perform a method of any of aspects 1 through 16.

Aspect 18: An apparatus for wireless communication at a first device, comprising at least one means for performing a method of any of aspects 1 through 16.

Aspect 19: A non-transitory computer-readable medium storing code for wireless communication at a first device, the code comprising instructions executable by a processor to perform a method of any of aspects 1 through 16.

It should be noted that the methods described herein describe possible implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

Although aspects of an LTE, LTE-A, LTE-A Pro, or NR system may be described for purposes of example, and LTE, LTE-A, LTE-A Pro, or NR terminology may be used in much of the description, the techniques described herein are applicable beyond LTE, LTE-A, LTE-A Pro, or NR networks. For example, the described techniques may be applicable to various other wireless communications systems such as Ultra Mobile Broadband (UMB), Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, as well as other systems and radio technologies not explicitly mentioned herein.

Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP, an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration).

The functions described herein may be implemented in hardware, software executed by a processor, firmware, or any combination thereof. If implemented in software executed by a processor, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. Other examples and implementations are within the scope of the disclosure and appended claims. For example, due to the nature of software, functions described herein may be implemented using software executed by a processor, hardware, firmware, hardwiring, or combinations of any of these. Features implementing functions may also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, and not limitation, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor. Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of computer-readable medium. Disk and disc, as used herein, include CD, laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of computer-readable media.

As used herein, including in the claims, "or" as used in a list of items (e.g., a list of items prefaced by a phrase such as "at least one of" or "one or more of") indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase "based on" shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as "based on condition A" may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase "based on" shall be construed in the same manner as the phrase "based at least in part on."

The term "determine" or "determining" encompasses a wide variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (such as via looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" can include receiving (such as receiving information), accessing (such as accessing data in a memory) and the like. Also, "determining" can include resolving, selecting, choosing, establishing and other such similar actions.

In the appended figures, similar components or features may have the same reference label. Further, various components of the same type may be distinguished by following the reference label by a dash and a second label that distinguishes among the similar components. If just the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the second reference label, or other subsequent reference label.

The description set forth herein, in connection with the appended drawings, describes example configurations and does not represent all the examples that may be implemented or that are within the scope of the claims. The term "example" used herein means "serving as an example, instance, or illustration," and not "preferred" or "advantageous over other examples." The detailed description includes specific details for the purpose of providing an understanding of the described techniques. These techniques, however, may be practiced without these specific details. In some instances, known structures and devices are shown in block diagram form in order to avoid obscuring the concepts of the described examples.

The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. A method for wireless communication at a first device, comprising:

monitoring for a set of reference signals from a second device using a set of measured beams;

selecting, by the first device, a subset of measured beams from the set of measured beams based at least in part on performing one or more measurements of the set of reference signals received on the set of measured beams, each measured beam of the subset of measured beams being associated with a set of beamforming weights; and

communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of measured beams, wherein the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of measured beams;

wherein the first device comprises a user equipment and each reference signal of the set of reference signals comprises a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

2. The method of claim **1**, further comprising:

determining, based at least in part on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of measured beams; and

determining one or more eigenvectors associated with the covariance matrix, wherein the one or more eigenvectors satisfy a threshold, and wherein the combination is based at least in part on the one or more eigenvectors.

3. The method of claim **1**, further comprising:

generating each measured beam of the set of measured beams based at least in part on a respective set of beamforming weights, wherein each respective set of beamforming weights corresponds to a direction of a plurality of directions, and wherein receiving the set of reference signals using the set of measured beams is based at least in part on generating each measured beam.

4. The method of claim **3**, wherein each beamforming weight of the respective set of beamforming weights comprises a weighting applied to an antenna element of a subset of antenna elements at the first device.

5. The method of claim **1**, wherein each reference signal of the set of reference signals corresponds to a multi-path component of a set of multi-path components, each multi-path component comprising a respective signal path between the first device and the second device.

6. The method of claim **5**, further comprising:

determining an angle of arrival associated with each multi-path component of the set of multi-path components, wherein selecting the subset of measured beams is based at least in part on the angle of arrival associated with each multi-path component of the set of multi-path components.

7. The method of claim **1**, further comprising:

determining a performance metric associated with communications between the first device and the second device, wherein a number of measured beams comprising the subset of measured beams is based at least in part on the performance metric.

8. The method of claim **7**, wherein the performance metric comprises a link budget, an effective spectral efficiency, a block error rate, a signal-to-interference-plus-noise ratio, a signal-to-noise ratio, or a reference signal received power ratio.

9. The method of claim **1**, wherein selecting the subset of measured beams comprises:

determining, based at least in part on the one or more measurements, one or more directional beams of the set of measured beams that satisfy a threshold, wherein the subset of measured beams comprises the one or more measured beams that satisfy the threshold.

10. The method of claim **1**, wherein the one or more measurements further comprise one or more reference signal received power measurements or one or more signal-to-interference-plus-noise ratio measurements.

11. The method of claim **1**, wherein the combination is based at least in part on maximum ratio combining, or equal gain combining, or one or more optimum combining strategies, or any combination thereof.

12. The method of claim **1**, wherein each reference signal of the set of reference signals is transmitted using one or more millimeter wave carrier frequencies.

13. The method of claim 12, wherein the one or more millimeter wave carrier frequencies are greater than about 24.25 gigahertz.

14. An apparatus for wireless communication at a first device, comprising:

a processor;

memory coupled with the processor; and

instructions stored in the memory and executable by the processor to cause the apparatus to:

monitor for a set of reference signals from a second device using a set of measured beams;

select, by the first device, a subset of measured beams from the set of measured beams based at least in part on performing one or more measurements of the set of reference signals received on the set of measured beams, each measured beam of the subset of measured beams being associated with a set of beamforming weights; and

communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of measured beams, wherein the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of measured beams;

wherein the first device comprises a user equipment and each reference signal of the set of reference signals comprises a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

15. The apparatus of claim 14, wherein the instructions are further executable by the processor to cause the apparatus to:

determine, based at least in part on the one or more measurements, a covariance matrix associated with a subset of antenna elements of a set of antenna elements at the first device and each set of beamforming weights associated with the subset of measured beams; and

determine one or more eigenvectors associated with the covariance matrix, wherein the one or more eigenvectors satisfy a threshold, and wherein the combination is based at least in part on the one or more eigenvectors.

16. The apparatus of claim 14, wherein the instructions are further executable by the processor to cause the apparatus to:

generate each measured beam of the set of measured beams based at least in part on a respective set of beamforming weights, wherein each respective set of beamforming weights corresponds to a direction of a plurality of directions, and wherein receiving the set of reference signals using the set of measured beams is based at least in part on generating each measured beam.

17. The apparatus of claim 16, wherein each beamforming weight of the respective set of beamforming weights comprises a weighting applied to an antenna element of a subset of antenna elements at the first device.

18. The apparatus of claim 14, wherein each reference signal of the set of reference signals corresponds to a multi-path component of a set of multi-path components, each multi-path component comprising a respective signal path between the first device and the second device.

19. The apparatus of claim 18, wherein the instructions are further executable by the processor to cause the apparatus to:

determine an angle of arrival associated with each multi-path component of the set of multi-path components, wherein selecting the subset of measured beams is based at least in part on the angle of arrival associated with each multi-path component of the set of multi-path components.

20. The apparatus of claim 14, wherein the instructions are further executable by the processor to cause the apparatus to:

determine a performance metric associated with communications between the first device and the second device, wherein a number of measured beams comprising the subset of measured beams is based at least in part on the performance metric.

21. The apparatus of claim 20, wherein the performance metric comprises a link budget, an effective spectral efficiency, a block error rate, a signal-to-interference-plus-noise ratio, a signal-to-noise ratio, or a reference signal received power ratio.

22. The apparatus of claim 14, wherein the instructions to select the subset of beams are executable by the processor to cause the apparatus to:

determine, based at least in part on the one or more measurements, one or more measured beams of the set of measured beams that satisfy a threshold, wherein the subset of measured beams comprises the one or more measured beams that satisfy the threshold.

23. The apparatus of claim 14, wherein:

the one or more measurements further comprise one or more reference signal received power measurements or one or more signal-to-interference-plus-noise ratio measurements.

24. An apparatus for wireless communication at a first device, comprising:

means for monitoring for a set of reference signals from a second device using a set of measured beams;

means for selecting, by the first device, a subset of measured beams from the set of measured beams based at least in part on performing one or more measurements of the set of reference signals received on the set of measured beams, each measured beam of the subset of measured beams being associated with a set of beamforming weights; and

means for communicating with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of measured beams, wherein the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of measured beams;

wherein the first device comprises a user equipment and each reference signal of the set of reference signals comprises a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

25. A non-transitory computer-readable medium storing code for wireless communication at a first device, the code comprising instructions executable by a processor to:

monitor for a set of reference signals from a second device using a set of measured beams;

select, by the first device, a subset of measured beams from the set of beams based at least in part on performing one or more measurements of the set of reference signals received on the set of measured beams, each measured beam of the subset of measured beams being associated with a set of beamforming weights; and

communicate with the second device using a dynamic set of beamforming weights that is formed using a combination of beamforming weights from each set of beamforming weights associated with the subset of measured beams, wherein the dynamic set of beamforming weights is different from each set of beamforming weights associated with the subset of measured beams;

wherein the first device comprises a user equipment and each reference signal of the set of reference signals comprises a synchronization signal block, a channel state information reference signal, or a demodulation reference signal, or any combination thereof.

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